INDIA. GEOLOGICAL SURVEY.

A MANUAL

OF

THE GEOLOGY OF INDIA.

PART II: EXTRA-PENINSULAR AREA.

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Sub-division of the extra-peninsular area.—The distinctions in geological characters between the peninsular and extra-peninsular areas of India have already been explained, and the reasons for treating the two regions separately have been sufficiently stated in the introductory chapter; whilst the descriptions of the tertiary, and still more of the post-tertiary, formations of the Peninsula furnish a natural passage to the extra-peninsular area. This is geologically an intrinsic portion of the Asiatic continent, whilst peninsular India is not.

Imperfect as is our knowledge of the geology of the Indian Peninsula, our acquaintance with the geological structure of the mountain ranges west of the Indus, of the Himalayas, and of the countries east and north-east of the Bay of Bengal, is even more fragmentary. Occasionally wide areas intervene, such as Nepal and the outer hills of the Afghan highlands, from which Europeans are rigidly excluded, and, even when no political difficulties exist, the physical impediments to surveying are of the most serious description. Many parts of the mountainous barrier which almost surrounds India are, from their great elevation and rigorous climate, only habitable for a short period of the year, and even then their exploration is a matter of difficulty; population is sparse, and roads either difficult or wanting throughout the whole tract. To the eastward, in the damper regions of Assam, Sylhet, and Burma, the denseness of the forest throughout nearly the whole of the country, and the impenetrable undergrowth of creepers, canes, bamboos, and shrubs, render the examination of the rocks toilsome, tedious, and unsatisfactory. To crown the whole, throughout extra-peninsular India, with the exception of Sind and the Panjáb, the geology is greatly obscured by the disturbance and, in many parts, the metamorphism which the rocks have undergone.

Owing to these various drawbacks, it is not practicable to treat the geology of extra-peninsular India as has been done in the case of the peninsular area, and to describe each formation throughout the whole region by itself. Having to deal with fragmentary and isolated observations, varying greatly in their amount of detail, it appears best to take each geological tract separately; and this arrangement is facilitated by the fact that there is a wide distinction between different parts of the region, both in the formations represented, and in the physical features of the geology, such as the directions of the mountain chains. The plan that will be adopted in describing the extra-peninsular tracts will be to commence at the west with Sind, as the rocks of that province are not only closely connected with the tertiary formations of Cutch and Kattywar, described in the fourteenth chapter, but are also of importance as affording a better series of the tertiary beds, so widely developed in extra-peninsular India, than is known elsewhere in Southern or South-Eastern Asia.

The following regions will therefore be separately described:—

I. Sind.
II. Panjáb hills west of the Jhelum.
III. Himalayas.
IV. Assam, Sylhet, Chittagong, &c.
V. Burma.

I. Sind:—**Physical geography of Western Sind.**—The greater part of the province of Sind is included in the Indo-Gangetic plain, already described in Chapter XVII; Eastern Sind, beyond the limits of the Indus alluvium, consists chiefly of sand-hills, and the rock area of the province is almost limited to the ranges of hills on the western or Baluchistán frontier, and a few isolated ridges in the alluvium; the most important exposures amongst the latter being those near Sukkur (Sakhar) and Rohri (Roree).

The province is commonly divided into Upper and Lower Sind, the former lying north, the latter south of Sehwan. Upper Sind consists of a broad alluvial plain on both sides of the river, interrupted near Sukkur and Rohri by the ridges of limestone already mentioned, and bounded to the westward by a north and south mountain chain, known as the Khirthar,[1] forming the boundary between Sind and Baluchistán, and rising in places to 6,000, and even in one spot to 7,000, feet above the sea. Lower Sind, west of the Indus, consists of a series of parallel north and south ridges of no great height, seldom exceeding 2,000 feet above the sea, but much loftier to the north than to the south, where they almost disappear in an undulating plain near the coast. Many of

[1] This range in all the older maps is united with other hills on the western border of Sind, and the whole is called the Hála range. No such range is recognised in the country. There is a Hála pass, not in the Khirthar range, but in another much smaller ridge south of Sehwan.

these ridges are simple anticlinals, the axes being formed of the massive nummulitic limestone of which the highest portion of the Khirthar also consists. The Khirthar range terminates in Lower Sind some distance south of Sehwan; other ridges, however, both east and west of this main range, extend farther to the south. East of the Indus there is an isolated low range of limestone hills, on the northern extremity of which stands the town of Hyderábád, and there is another similar rise at Tatta.

The hills of Baluchistán, west of Sind, are very imperfectly known; for some distance from the Sind frontier they form ranges running north and south parallel to the Khirthar, but farther west they assume an east and west direction. They are principally composed of tertiary rocks, like the hills of Sind, but at Kelat itself, and in a few other localities, older formations have been discovered,[1] and some apparently extensive igneous rocks also occur.

Rock formations.—The rocks found in Sind,[2] as already noticed, belong chiefly to the tertiary epoch, but in one locality some cretaceous beds crop out from beneath the higher formations. The following is a list of the different groups, exclusive of the alluvium:—

Name.	Sub-divisions.	Approximate thickness.	Supposed geological age.	Remarks.
1. MANCHHAR	upper	5,000	*pliocene.*	Apparently representative of the Siwaliks proper.
	lower	3,000 to 5,000	*lower pliocene or upper miocene.*	
2. GAJ	......	1,000 to 1,500	*miocene.*	
3. NARI	upper	4,000 to 6,000	*lower miocene?*	
	lower	100 to 1,500	*upper eocene.*	
4. KHIRTHAR	upper	500 to 3,000	*eocene.*	Nummulitic limestone.
	lower	6,000?	*eocene.*	The base not determined.
5. RANIKOT	......	2,000	*lower eocene.*	
6. TRAPS	......	40 to 90	*upper cretaceous.*	Representative of Deccan and Malwa trap.
7. CRETACEOUS	*a. Cardita Beaumonti* beds	350 to 450	*cretaceous.*	
	b. Sandstones	700		
	c. Hippuritic limestone	320		Base not exposed.

[1] Cook, Trans. Med. Phys. Soc. Bombay, 1860, VI, pp. 1,45; Carter, Jour. Bombay Br. R. A. S., VI, p. 184. It is possible that some of the igneous rocks described as occurring may be interstratified and representative of the Deccan trap, as in Sind.

[2] This description is taken partly from the accounts of Sind geology given in Rec. G. S. I., IX, pp. 8—22, XI, pp. 161—173, and partly from manuscript notes. Some details were given previously, Mem. G. S. I., VI, pp. 1—12. The earliest description of the geology of Sind was by Vicary, Q. J. G. S., 1847, p. 334. The fossils obtained by Vicary and others were described in Messrs. D'Archiac and Haime's great work, the "Description des animaux fossiles du groupe Nummulitique de l'Inde," published in 1853.

Of these rocks, the lower Khirthars and the Ranikot beds may be, to some extent, representative of each other. On the river Gáj, which traverses the Khirthar range in Upper Sind, a thickness of at least 25,000 feet of strata is exposed, none of the fossiliferous beds being of older date than eocene; but some of the rocks towards the base of the section beyond the Sind frontier correspond so well with the description given by Dr. Cook of strata in which he found mesozoic fossils (*Ammonites*, &c.) in Kelat, that these bottom beds on the upper Gáj, which are only seen west of the British frontier, may very probably be of cretaceous age. There is, however, no resemblance between any of the lower beds on the Gáj and the cretaceous rocks of the Laki range.

Cretaceous beds.—The only locality in Sind, in which beds of older date than eocene have been identified, is in a range of hills running due south from the neighbourhood of Sehwan, and generally known to Europeans as the Laki range,[1] from the small town of Laki near the northern extremity. South-west of Amri on the Indus, a number of very dark-coloured hills are seen in this range; they contrast strongly with the cliffs of grey and whitish nummulitic limestones behind them. These dark hills consist of cretaceous beds, but the lowest member of the series is only exposed in a single spot, at the base of a hill known as Bárrah, lying about 10 miles south-west of Amri. The whole range here consists of three parallel ridges, the outer and inner composed of tertiary rocks; while the intermediate one consists of cretaceous beds, faulted to the eastward against the lower eocene strata and dipping under them to the westward. Close to the fault some whitish limestone is found, compact and hard; the lower portion pure; the upper portion, often containing ferruginous concretions, is sandy, gritty, and forms a passage into the overlying sandstones. The base of this limestone is not seen; the whole thickness exposed is a little over 300 feet, and the length of the outcrop does not exceed half a mile. The limestone is fossiliferous, and contains echinoderms and mollusca, but it is so hard and homogeneous that nothing that has been obtained from it can be easily recognised, except one fragment of a hippurite. This fossil is, however, of great importance, because it shews that the white limestone may very probably be an eastern representative of the hippuritic limestone, so extensively developed in Persia, and found in numerous localities[2] from Tehrân to east of

[1] This range has no general name, different portions being known by a number of local terms. It is one of the ranges which combines to form the Hála range of Vicary and other writers, and the name is less inappropriate in this case, for there is an unimportant pass through the chain known as the Hála Lak. Different portions of the range are known as Tiyûn, Kára, Eri, Surjána, &c. The range is very incorrectly represented on the maps.

[2] Eastern Persia, II, pp. 457, 485.

Karmán in longitude 58°, just ten degrees west of the Laki range in Sind. Of course the same formation may be found in the intervening country, the geology of which is unknown. The precise position of the Persian hippuritic limestone in the cretaceous series has not been determined, but the European formation, which is very similar and probably identical, is of the age of the lower chalk (turonian).

The sandstones resting on the hippuritic limestone occupy a considerable tract around Bárrah hill, and extend for about 3 miles from north to south. They are also seen at Jakhmari to the northward, and in one or two other places in the neighbourhood. They are gritty and conglomeratic, frequently calcareous, and contain a few bands of shale, usually of a red colour. The prevailing colour on the weathered surfaces is dark brown or purple, many of the beds being highly ferruginous. On the top of the sandstones is a thick bed of dark-coloured impure limestone, containing oyster shells, and occasionally large bones, apparently of reptiles; none, however, have been found sufficiently well preserved for identification.

In one place a bed of basalt, about 40 feet thick, has been found interstratified in the sandstones, and it is possible that the band may exist elsewhere, but it has hitherto remained undetected. The position of this bed of basalt on the face of a hill called Bor, about 13 miles north of Ranikot, is at an elevation of 300 or 400 feet above the base of the sandstones, and about twice as much beneath the main band of interbedded trap, to be described presently.

The highest sub-division of the cretaceous formation consists of soft olive shales and sandstones, usually of fine texture. The sandstone beds are thin, and frequently have the appearance of containing grains of decomposed basalt or some similar volcanic rock, or else fine volcanic ash. A few hard bands occur, and occasionally, but rarely, thin layers of dark olive or drab impure limestone. Gypsum is of common occurrence in the shales.

Palæontology.—The olive shales are highly fossiliferous, the commonest fossil being *Cardita beaumonti*,[1] a peculiar, very globose species, truncated posteriorly, and most nearly allied to forms found in the lower and middle cretaceous beds of Europe (neocomian and gault). This shell is extremely abundant in one bed, about 200 to 250 feet below the top of the cretaceous series, but is not confined to this horizon. *Nautili* also occur, the commonest species closely resembling *N. labechei*[2] of Messrs. D'Archiac and Haime, but differing in the position of the siphuncle. This form appears undistinguishable from *N. bouchardianus*, found in the upper cretaceous Arialur beds of Pondicherry, and at a lower

[1] D'Archiac and Haime, An. foss. Groupe Num., p. 253, pl. xxi, fig. 14.
[2] T. c. p. 338, pl. xxxiv, fig. 12.

cretaceous horizon in Europe. A second *Nautilus* resembles *N. subfleuriausianus*, another eocene Sind species, in form, and is also allied to some cretaceous types. Several *Gasteropoda* occur, especially forms of *Rostellaria*, *Cypræa*, *Natica* and *Turritella*, but none are very characteristic. Two forms of *Ostrea* are common—one of them allied to the tertiary *O. flemingi* and to the cretaceous *O. zitteliana*, but distinct from both. The only mollusk which certainly passes into the Ranikot beds is *Corbula harpa*. Two echinoderms have been found—one is an *Epiaster*, an almost exclusively cretaceous genus, only one or two tertiary species having been found; the other is an aberrant form of *Echinolampas*. Two or three corals complete the list of invertebrate fossils found in the olive shales.

In the lower part of the beds with *Cardita beaumonti*, however, some amphicœlian vertebræ were found, which Mr. Lydekker has ascertained to be crocodilian. All amphicœlian crocodiles are mesozoic, and the present form must be one of the latest known. So far as it is possible to form an opinion from very fragmentary materials, the vertebræ in question appears more nearly allied to the Wealden *Suchosaurus* than to any other form hitherto described. It has, however, been already shewn, when writing of the Gondwána flora, that the distribution of *Reptilia* in past ages was not the same in India as in Europe.

The fossils of the *Cardita beaumonti* zone require much fuller examination and comparison than they have hitherto received, but sufficient has been ascertained to shew that they have a distinctly cretaceous character, and that the limit of tertiary formations must be drawn above them. As will be seen in the description of the Panjáb Salt Range in the next chapter, it is probable that this peculiar band of olive-coloured shales is represented by similar beds in that locality also. It has, however, not hitherto been recognised in Baluchistán or in the Western Panjáb, south of the Salt Range.

Deccan trap.—Mention has already been made of one bed of basalt intercalated in the sandstones above the hippuritic limestone: a much more important band of the same igneous rock has been traced, resting upon the *Cardita beaumonti* beds, throughout a distance of 22 miles from Ranikot to Jakhmari, about 17 miles south of Sehwan, wherever the base of the Ranikot group, the lowest tertiary formation, is exposed. The thickness of this band of trap is trifling, and varies from about 40 to about 90 feet. Apparently in some places the whole band consists of two lava flows similar in mineral character, except that the upper is somewhat ashy, and contains scoriaceous fragments; the higher portion of each flow is amygdaloidal, and contains nodules of quartz, calcedony and calcite, and in places the nodules are surrounded by green earth, as is

so frequently the case in the Deccan traps. Another characteristic accessory mineral, common also in the traps of the Deccan and Malwa, is quartz with trihedral terminations. The basaltic trap of the Laki hills is apparently of subaërial origin, although it rests conformably on the marine (or estuarine?) *Cardita beaumonti* beds. There is nothing in the igneous bed to indicate its having consolidated otherwise than in the air, and the structure differs altogether from that of subaqueous volcanic tuffs.

The evidence that this band of basaltic rock is interstratified and not intrusive is ample; throughout the whole distance the trap is found in precisely the same position between the lowest beds of the Ranikot group and the highest cretaceous strata, and apparently perfectly conformable to both. The close resemblance in mineral character and the similarity of geological position at the base of the tertiary beds shew that this band must be in all probability a thin representative of the great Deccan and Malwa trap formation, and the occurrence of a second bed at a lower horizon, interstratified with rocks of cretaceous age, tends strongly to confirm the inference drawn from the relations of the traps to cretaceous and tertiary rocks in the Narbada valley, that the great volcanic formation of Western India must be classed as upper cretaceous.

Ranikot group.—The name of the lowest tertiary sub-division is derived from a hill fortress of the Sind Amirs, situated in the Laki range of hills, and known as Rani-jo-kot, or Ranikot, and also as Mohan-kot, from the Mohan stream, which traverses the fortification. The Ranikot group is much more extensively developed in Sind than the underlying cretaceous beds, for although it is confined to Lower Sind, and although its base is only seen in the Laki range, north of Ranikot, its upper strata occupy a considerable tract of country, about 26 miles long from north to south by about 12 in breadth, north-west of Kotri, and another even larger exposure, about 36 miles long, occurs, extending from north of Jhirak (Jhirk, Jhirruk, Jerruck or Jurruk) to Tatta. In the Laki range, the Ranikot beds are seen for about 35 miles, but the outcrop is never more than 2 or 3 miles broad, and one small inlier is exposed to the west of Ranikot.

All the lower portion of the Ranikot group, including by far the greater portion of the beds, consists of soft sandstones, shales and clays, often richly coloured and variegated with brown and red tints. Gypsum is of frequent occurrence; some of the shales are highly carbonaceous; and in one instance a bed of coal (or lignite) nearly 6 feet thick was found, and a considerable quantity of the mineral extracted.[1] The quality was, however, poor, and from the quantity of iron-pyrites present, the coal decomposed rapidly, and was liable to spontaneous combustion

[1] Mem. G. S. I., VI., p. 13.

when exposed, whilst the deposit was found to be a small patch, not extending more than about 100 yards in any direction. Some of the more pyritous shale is used in the manufacture of alum. The only fossils found in the lower portion of the Ranikot group, with the exception of a few fragments of bone, have been plants, some dicotyledonous leaves, hitherto not identified, being the most important. All the Ranikot beds, except towards the top of the group, have the appearance of being of fresh-water origin, and are probably fluviatile.

A variable portion of the group, however, towards the top, consists of highly fossiliferous limestones, often light or dark brown in colour, interstratified with sandstones, shales, clays, and ferruginous bands. These are the lowest beds in Sind containing a distinctly tertiary marine fauna. The brown limestones are well developed around Lynyan, east of Band Vero and north-west of Kotri, and throughout the area of Ranikot beds near Jhirak and Tatta. In this part of the country there appears to be a complete passage upwards into the overlying nummulitic limestone (Khirthar); but in the Laki range, the upper marine beds of the Ranikot group are poorly represented or wanting, and it is evident that they were removed by denudation before the deposition of the Khirthar limestone, for the latter is seen at Hothian Pass resting upon their denuded edges.

The greatest thickness of the Ranikot group in the Laki range, where alone, as has already been explained, the base of the group is visible, is about 2,000 feet, but generally the amount is rather less, about 1,500. It must, however, be recollected that in this locality some of the upper marine beds are wanting, and as these marine limestones and their intercalated shales, sandstones, &c., are 700 or 800 feet thick, in places northwest of Kotri, it is evident that the original development of the group exceeded the 2,000 feet seen in the Laki range.

Palæontology.—The following are some of the commonest or most important fossils of the Ranikot group. The large collections made by the Geological Survey have as yet only been partially examined, and the lists of fossils given can be considered only preliminary,[1] many of the commonest species being undescribed forms :—

CEPHALOPODA.

Nautilus subfleuriausianus.
N. deluci.
N. forbesi.

[1] As in other lists in this chapter, most of the names are taken from D'Archiac and Haime's "Animaux fossiles du groupe nummulitique de l'Inde." In this work, however, species from upper cretaceous, eocene and miocene beds are described; until the rocks of Sind were surveyed, the distribution of the fossils was not known, although indications of a probable sub-division had been pointed out by D'Archiac and Haime, (t. c. p. 359), and it had been shewn by Jenkins (Q. J. G. S., 1864, p. 65), and by Martin Duncan (ib., p. 66, and Ann. Mag. Nat. Hist. Ser. 3, Vol. XIII, p. 295), that some of the fossils described indicated the presence of miocene beds.

GASTEROPODA.

Rostellaria angistoma.	*Voluta jugosa.*
R. prestwichi.	*Natica longispira.*
R. fusoides.	*Nerita (Velates) schmedeliana.*
Terebellum distortum.	*Turritella angulata*, var.
T. plicatum.	*T. assimilis.*

LAMELLIBRANCHIATA.

Corbula harpa.	*Ostrea flemingi.*
Vulsella legumen.	*O. vesicularis.*
Spondylus roualti.	

BRACHIOPODA.

Terebratula, cf. *subrotunda.*

ECHINODERMATA.

Schizaster, sp.	*Echinolampas*, cf. *subsimilis.*
Hemiaster digonus.	*Temnopleurus valenciennesi.*
Eurhodia morrisi.	*Salenia*, 2 sp.
Prenaster, sp.	*Phymosoma*, sp.
Toxobrissus, sp.	*Porocidaris*, sp. (spines).
Conoclypeus, sp.	*Cidaris halaensis.*

ANTHOZOA.

Trochocyathus vandenheckei.	*Montlivaltia jacquemonti.*
Cyclolites vicaryi.	

FORAMINIFERA.

Operculina canalifera.	*Nummulites irregularis.*
Nummulites spira.	*N. leymeriei.*

In the above list the majority of forms, such as the *Foraminifera*, the majority of the *Echinodermata* and *Gasteropoda* are lower tertiary, but still there is a very distinct admixture of species with cretaceous affinities, such as the *Nautili*, all of which are connected rather with cretaceous than with tertiary types, the *Terebratula*, which cannot be distinguished from one of the commonest upper mesozoic species, and forms of *Salenia*, *Cyclolites*, &c. *Corbula harpa* is the only form hitherto recognised that is also found in the upper cretaceous olive shales, but a variety of the same shell is also found in the Nari beds.

Cretaceous and lower tertiary rocks of Baluchistan.—All the rocks described in the last few pages as occurring below the nummulitic limestone or Khirthar group are found in Lower Sind, and, so far as is known, are confined to a tract near the right bank of the river Indus. Farther to the westward the series of older tertiary and upper cretaceous rocks has not been thoroughly examined, but the information hitherto obtained appears to shew that the strata below the nummulitic limestone are very different in character from those found in Lower Sind. In

Baluchistán, west of the frontier of Upper Sind, lower beds crop out from beneath the massive nummulitic (Khirthar) limestone, forming the crest of the intervening range of hills, and on the banks of the Gáj river which traverses the range south-west of Mehar, a series of more than 10,000 feet of strata is exposed below the Khirthar group. The following is a rough section of the rocks thus exposed, the thickness being merely an approximation :—

		Feet.
Khirthar	1. Massive nummulitic limestone, forming the crest of the Khirthar range	1,200
	2. Shales, marls and clays, mostly dark-olive in colour, abounding in *Nummulites*	500
	3. Hard grey limestone, with *Nummulites*	60
	4. Argillaceous limestone, shales and clays, olive and bluish grey in colour, abounding in *Nummulites*	400
Lower Khirthar	5. Unfossiliferous olive and bluish-grey clays and nodular shales, no limestone bands	1,500
	6. Pale-brown sandstones in thick beds with vegetable markings	1,000
	7. Fine greenish-white sandstone and shale, some of which is carbonaceous	500
	8. Dark-brown limestone and dark-green argillaceous beds, with *Nummulites*	100
	9. Pale-grey argillaceous limestone, with but few fossils; one band towards the base contains *Nummulites* and *Alveolinæ*	200
? Cretaceous	10. Fine dark-coloured shales, unfossiliferous	3,000
	11. Very fine grained homogeneous thin-bedded limestones, white, red, grey, or ochrey in colour, unfossiliferous, forming a conspicuous range	1,200
	12. Hard grey shales with calcareous bands from an inch or two to a foot in thickness	2,500
	The base not exposed.	
		12,160

About this section the first point to be observed is that none of the beds resemble those seen in Lower Sind sufficiently to enable any of the strata of the two localities to be identified with certainty. The sandstone No. 6 may correspond to the sands and clays of the Ranikot group, but there is no great similarity, and nothing in the above section appears to represent the fossiliferous brown limestones of the Ranikot group, the Deccan trap, the olive shales with *Cardita beaumonti*, or any other of the cretaceous beds in the Laki hills. So far, indeed, as the section on the Upper Gáj river is concerned, all the rocks exposed might be referred to the tertiary epoch and classed as lower eocene; no marked break intervenes anywhere, nor are there any fossils below the argillaceous limestone with nummulites, No. 9, to shew the age of the beds. But, as has

already been noticed, farther to the westward, near Khozdár, in Baluchistán, Dr. Cook discovered *Ammonites* [1] in some argillaceous beds, passing upwards into red and white limestone, and it appears probable from the description that the latter is identical with the fine-grained thin-bedded limestone, No. 11, of the preceding section, whilst the argillaceous beds may be the same as No. 12.

The following section, abridged from that given by Dr. Cook,[2] shews the nature of the rocks between Kelat and Khozdar, the latter place lying about 70 miles north-north-west of the section on the upper Gáj river :—

		Feet.
Eocene	1. Compact white or reddish-white limestone containing *Nummulites, Orbitolites, Orbitoides, Alveolina,* &c. (This is doubtless the Khirthar limestone.) Thickness unknown; probably more than	1,000
	2. Limestone strata, differing in character, compact, subcrystalline, saccharoid, at times cretaceous, containing *Nummulites (Assilina), Alveolina,* and minute indistinct *Foraminifera* and passing downwards into coloured argillaceous strata . . . . . . ?	200—500
Mesozoic	3. More or less compart, fine grained red and white limestone interleaved with slabs of flint or chert, the upper part containing one or two massive strata of an excessively hard limestone, abounding in *Orbitoides, Orbitolina,* and *Operculina,* the lower strata becoming argillaceous and shaly and containing (rarely) *Ammonites* .	? 2,000
	4. Dark-blue fossiliferous limestone containing strata yielding lead ore (galena and carbonate of lead) .	? 2,000
	5. Clay slate	? 2,500

It is true that the precise relations of many of these beds are far from clear. Thus, in the valley of Kelat, the red and white limestone appears to underlie strata containing *Orthoceratites*. This may, however, be due to faulting or inversion. It is probable that several different groups of beds occur near Kelat, for amongst the fossils, besides *Orthoceratites, Ammonites* of jurassic types, *Ceratites, Crioceras, Scaphites* and *Belemnites* occur, and whilst some of the forms are typically cretaceous, others can scarcely be newer than triassic.

It is not impossible that the limestone bands in No. 3, containing *Orbitoides* and other *Foraminifera*, may belong to the tertiary series and

[1] Jour. Bombay Br. R. A. S., VI, pp. 186, 188.

[2] Bombay Med. Phys. Soc. Trans, 1860, VI, p. 100. The bed numbered 2 in the section is called upper cretaceous by Dr. Cook, but with a mark of doubt. This was perhaps in accordance with the views as to the classification of the beds beneath the nummulitic limestone formerly held by Dr. Carter, but subsequently modified by him. See Jour. Bombay Br. R. A. S., IV, pp. 93, 95, V., p. 635, and "Geological papers on Western India," pp. 623, 626, 699, 700, footnote, &c.

not to the group with which they are associated. The banded fine grained white or red and white limestone is a conspicuous and important bed, and is probably widely developed in Baluchistán. It was found by Dr. Cook at several places south and south-west of Kelat; it occurs, as already shown, on the upper Gáj river west of the Khirthar range, forming a range of hills known as Parh, and a rock of precisely the same mineral character appears 130 miles further south on the coast at a small hill called Gadáni, about 25 miles north-west of Karáchi. If, as appears probable, this peculiarly fine limestone or calcareous shale (for the rock in places appears argillaceous) belong to the upper portion of the cretaceous series, it will serve to mark that horizon in Baluchistán and facilitate the recognition of the indistinct limit between mesozoic and tertiary. There is, however, a great appearance of passage between all these formations.

Returning to the beds of the Gáj section, the gradual passage upwards from the shales, marls, and clays with *Nummulites*, Nos. 2, 3, and 4 of the section, into the massive nummulitic limestone is worthy of notice. A similar passage takes place locally in Lower Sind, and it appears best to consider the shales and marls as the lower portion of the same group as the limestone. The six thousand feet of rocks remaining between the nummulitic shales and the banded limestones of supposed cretaceous age may be classed as lower Khirthar; they very possibly represent the Ranikot group, but, as already noticed, there is no distinct mineralogical or palæontological connexion. The nummulites found in No. 8 in the middle of this lower Khirthar group comprise *N. obtusa*, *N. granulosa*, *N. leymeriei*, *N. spira*, and other species common in the Khirthar limestone itself.

It is probable that the beds below the Khirthar limestone extend throughout a large tract in Baluchistán, on the west side of the Khirthar range, for similar beds are seen, from the crest of the hills, cropping out to the westward as far north as Dháryáro and Kutto-jo-Kabar (the dog's tomb), the culminating point of the range due west of Lárkána. Again, west of the Habb river, forming the boundary of Sind near the sea, the whole Khirthar formation appears composed of shales, marls and sandstones, closely resembling in character those of the lower Khirthar group west of Upper Sind, and an enormous thickness of similar beds is found extensively developed in Makrán.[1]

Khirthar group.—Although this group, named from the great frontier range of hills already noticed, is, when the underlying shales and sandstones are excluded, inferior in total thickness to several

[1] Eastern Persia, vol. ii., pp. 460, 473.

other sub-divisions of the tertiary series in Sind, it comprises by far the most conspicuous rock, the massive nummulitic limestone. Of this formation all the higher ranges in Sind consist. It forms the crest of the Khirthar throughout, and all the higher portions of the Laki range, of the Bhit range south-west of Manchhar lake, and of several smaller ridges, and consists of a mass of limestone, varying in thickness from a few hundred feet in Lower Sind to about 1,000 or 1,200 at the Gáj river, and probably 2,000, or even 3,000, farther north. The colour is usually pale, either white or grey, sometimes, but less frequently, dark grey; the texture varies from hard, close, and homogeneous, breaking with a conchoidal fracture, to soft, coarse and open. Ordinarily, the nummulitic limestone is tolerably compact, but not crystalline, and chiefly composed of *Foraminifera*, especially *Nummulites*, whole or fragmentary; corals, sea-urchins and mollusks also abound, but the two latter very frequently only weather out as casts.

Throughout Northern Sind, except near Rohri, no beds are seen beneath the Khirthar limestone, and the rocks which crop out west of the Sind frontier from beneath the main limestone band have already been described. The remarkable range of low hills, surrounded by Indus alluvium, and extending for more than 40 miles south from Rohri, consists of nummulitic limestone having a low dip to the westward, and beneath the limestone forming the eastern scarp of the hills, on the edge of the alluvial plain, a considerable thickness of pale-green gypseous clays is exposed, with a few bands of impure dark limestone and calcareous shale. No *Foraminifera* have been found in these beds, although *Nummulites* abound in the limestone immediately overlying; several species of mollusca occur, but none are characteristic, and it is far from clear whether the green clays and their associates are merely thick bands intercalated in the limestone, or whether they belong to a lower group. Probably these argillaceous beds of the Rohri hills represent some of the marls, shales and clays forming the lower portion of the upper Khirthar group on the Gáj river.

In some places west of Kotri, a band of argillaceous and ferruginous rock is found close to the base of the Khirthar group. This rock weathers into laterite; it is mainly composed of brown hæmatite, and appears to be found over a considerable area near Kotri and Jhirak. It is impossible to avoid suggesting its identity with the ferruginous lateritic bed found in a similar position in Guzerat, Cutch, the Salt range, and the Sub-Himalayan region.

It has already been mentioned that in the Laki range the nummulitic limestone rests unconformably on the Ranikot group. The Khirthar group here cannot be much more than 500 or 600 feet thick, and

consists entirely of limestone. To the south-east, towards Kotri and Tatta, there is no unconformity between the Ranikot and Khirthar groups, but on the contrary there is an almost complete passage between the two, and the limestone of the latter becomes much split up and intercalated with shales and sandy beds. This is even more the case further to the south-east in Cutch,[1] where, as was noticed on a previous page, the whole group consists of comparatively thin beds of limestone, interstratified with shales. To the south-west, near the Habb river, the massive limestone dies out altogether, and although it is well developed in the southernmost extremity of the Khirthar range near Karchat, about 50 miles south of Sehwan, it disappears entirely within a distance of 12 or 14 miles, and in the ranges on the Habb river is entirely replaced by shaly limestones, shales, and thick beds of sandstone. Some rather massive beds of nummulitiferous dark-grey limestone, very different in character from the pale-coloured Khirthar limestone, are found west of the Habb, but their precise position in the series is not known, and the rocks appearing from beneath the Nari group, in the place of the Khirthar limestone, consist of shales and sandstones, with some calcareous bands abounding in nummulites, and closely resembling, both in character and in the species of *Foraminifera* they contain, the nummulitic shales beneath the massive limestone on the Gáj river. It is not known to what extent the typical Khirthar limestone is developed in Baluchistán; around Kelat, to the northward, this band appears to be extensively exposed, but to the westward, near Gwådar, the rocks supposed to represent the older tertiary beds consist of an immense thickness of shales, shaly sandstones, and unfossiliferous calcareous bands, resembling the lower Khirthars of the Gáj, and the beds of the Habb valley, and limestones with nummulites are of unfrequent and local occurrence. It is thus evident that the Khirthar limestone, although it is so conspicuous in most parts of Sind, and although it attains a considerable thickness, is not by any means universally distributed.

Palæontology.—The most characteristic fossils[2] of the Khirthar group are *Nummulites* and *Alveolina;* neither the genera, nor, as a rule,

[1] See *ante*, p. 345.

[2] The following fossils from the eocene formations of Western India are figured on plate XV :—

Fig. 1. *Voluta jugosa.*
„ 2. *Nerita schmedeliana*, 2a. cast of the same, half natural size.
„ 3. *Pecten labadyei.*
„ 4. *Vulsella legumen.*
„ 5. *Echinolampas discoideus*, ½ size.
„ 6. *Eurhodia morrisi.*
„ 7. *Orbitoides papyracea.*
Fig. 8. *Orbitoides dispansa.*
„ 9. *Alveolina spheroidea,*
„ 10. *Nummulites garansensis.*
„ 11. *N. sublævigata.*
„ 12. *N. ramondi.*
„ 13. *N. obtusa.*
„ 14. *N. granulosa,*
„ 15. *N. leymeriei.*

the species are peculiar, but the extraordinary abundance of individuals renders it usually easy to recognise even small fragments of the rock by the organisms preserved in it. The following is a list of the commonest or most important fossils :—

GASTEROPODA.

Ovulum murchisoni, and other species.
Cerithium cf. *giganteum*.
Nerita schmedeliana, Pl. XV., fig, 2, 2*a*.

LAMELLIBRANCHIATA.

Pholadomya halaensis.
Corbula subexarata.
Cardita mutabilis.
C. subcomplanata.
Lucina gigantea.
Astarte hyderabadensis.
Crassatella sindensis.
C. halaensis.
Vulsella legumen, Pl. XV., fig. 4.
Ostrea vesicularis, var. (*O. globosa*, Sow.)

ECHINODERMATA.

Brissopsis scutiformis.
B. sowerbyi?
Schizaster, sp.
Eupatagus avellana.
Fibularia, sp.
Amblypygus, sp.
Conoclypeus pulvinatus.
Eurhodia calderi.
Echinolampas discoideus, Pl. XV, fig, 5.
E. sindensis.

FORAMINIFERA.

Orbitolites complanata.
Orbitoides dispansa, Pl. XV, fig. 8.
Patellina cooki.
Alveolina ovoidea.
A. spheroidea, Pl. XV, fig. 9.
Nummulites obtusa, Pl. XV, fig. 13.
Nummulites ramondi, Pl. XV, fig. 12.
N. biaritzensis.
N. beaumonti.
N. vicaryi.
N. granulosa, Pl. XV, fig. 14.
N. leymeriei, Pl. XV, fig. 15.

Many of the species named, and the foraminifera especially, are characteristically eocene, and there can be no question that the nummulitic limestone of India is a continuation of the same formation in Europe. Several species pass from the Ranikot beds into the Khirthar group; indeed, the principal palæontological differences between the two may be due to a change in conditions, the Khirthar being apparently a deeper water deposit than the Ranikot group.

Nari group.—The series of tertiary rocks above the Khirthar nummulitic limestone is superbly developed and very well seen in the hills on the frontier of Upper Sind, the culminating ridge of which is known as the Khirthar. The names of the tertiary groups over-

lying the nummulitic formation have consequently been derived from places in this range, and the Nari group takes its title from a stream which traverses the lower portions of the range, composed almost entirely of Nari beds, for a considerable distance, and issues from the hills nearly west of Johi, and west by north of Sehwan. The present sub-division comprises at the base the uppermost bands of limestone containing *Nummulites;* the species, however (*N. garansensis*, Pl. XV, fig. 10, and *N. sublævigata*, ib., fig. 11), being distinct from those so commonly found in the Khirthar sub-division, and the limestone itself being usually distinguished from that of the Khirthar group by its yellowish-brown colour, and by being in comparatively thin bands interstratified with shales and sandstones. Several other fossils, too, besides the nummulites, differ from those in the Khirthar beds. Not unfrequently, however, there is an apparent passage from the white or greyish-white Khirthar limestone into the yellow or brown Nari rock, and the two groups appear always to be perfectly conformable, but no intermixture of the characteristic species of nummulites has been detected, and the division between the Khirthar and Nari beds can always be recognised by the fossil evidence.

In some places the lower Nari beds consist almost entirely of brown and yellow limestones, but more frequently the limestone bands are subordinate; dark shales, and brown rather thinly-bedded sandstone forming the mass of the rocks. The limestone bands are often confined to the base of the group, and always diminish in abundance and thickness above, although they are occasionally found as much as 1,500 feet above the top of the Khirthar. The shales and fine sandstones, with occasional bands of limestone, constitute the lower Naris, and pass gradually into the coarser, massive, thick-bedded sandstones forming the greater portion of the group, and attaining a thickness of 4,000 or 5,000 feet on the flanks of the Khirthar range. With the sandstones a few bands of clay, shale, or ironstone, are interstratified, and bands of conglomerate occasionally occur. The Nari beds in their typical form extend throughout the eastern flank of the Khirthar range, and occupy a belt of varying width, from one or two to as much as 10 miles in breadth, between the underlying Khirthar and the overlying Gáj beds.

On the western side of the Bhagotoro hills, 4 or 5 miles south of Sehwan, there is a break in the Nari beds, and some variegated shales, clays and sandstones, richly tinted in parts with brown and red, and representing the massive sandstones of the upper Nari group, rest unconformably on the denuded edges of the lower Nari brown limestones and shales. The break is evidently local. To the east of the

Laki range the Nari beds are entirely wanting, and it appears very possible that they have never been deposited in this portion of the Indus valley. From the neighbourhood of Sehwan to Jhirak, Manchhar beds rest, with more or less unconformity, on the Khirthar, a very faint and imperfect representative of the Gáj group occasionally intervening. But west of the Laki range, throughout Lower Sind, the Nari beds are found exposed almost wherever the base of the Gáj group is seen; they increase in thickness to the westward, and the Habb valley, from the spot where the river first forms the boundary of British territory to the sea, consists entirely of these strata. There is, however, in this part of the country no longer any such marked distinction between the sub-divisions of the tertiary series as is found in the Khirthar range. The disappearance of the Khirthar limestone has already been mentioned, and with it the lower Nari limestones with *Nummulites garansensis* and *N. sublævigata* also disappear, so that it is no longer possible to draw a distinct line between the two groups, for the shaly beds at the base of the Naris are undistinguishable from similar rocks in the Khirthars. The calcareous shales, with the characteristic Khirthar nummulites, below, and the massive Nari sandstones above, are still recognisable, and the two groups can consequently still be traced, although the dividing line between them is obscured. Beds of brown limestone, too, full of *Orbitoides papyracea* (or *O. fortisi*, Pl. XV, fig. 7), a fossil closely resembling a nummulite, and associated in abundance with *N. garansensis* in the typical lower Nari limestones, occur in the Nari beds of the Habb valley; but instead of being found at the base, they appear in the middle of the group. Again, just as at the base of the Naris, there is a difficulty in distinguishing them from the Khirthar, so the beds at the top of the former group can only be separated by an arbitrary line from the overlying Gáj beds. In the Khirthar range the upper boundary of the Nari group, although there is no unconformity, is distinct and definite, limestones with marine fossils of the Gáj group resting immediately upon the upper Nari sandstones. But in Southern Sind bands of limestones, or calcareous sandstone, with marine fossils, some of which are well-marked Gáj species, occur in the upper part of the Nari group, whilst limestone bands with the Nari *Orbitoides papyracea* are found in the Gáj.

Palæontology.—The sandstones, which form so large a portion of the Nari group, have hitherto proved destitute of animal remains, and in the typical area in Upper Sind, no beds with marine fossils are intercalated in the upper portion of the group, but the occasional interstratifications of shales and clays often contain fragments of plants, and some ill-marked

impressions, probably due to fucoids, have been found in the sandstones themselves. There appears a probability that these sandstones may be of fluviatile and not of marine origin.

In the limestones towards the base of the Nari group, many marine fossils have been obtained, the following being some of the more important:—

GASTEROPODA.

Terebellum obtusum.	*Natica patula.*
Cypræa nasuta.	*N. sigaretina.*
Voluta jugosa, Pl. XV, fig. 1.	*Siliquaria granti.*
V. dentata.	*Solarium affine.*
Triton davidsoni.	*Trochus cumulans.*
	Phasianella oweni.

LAMELLIBRANCHIATA.

Corbula harpa.	*Pecten labadyei*, Pl. XV, fig. 3.
Venus granosa, Pl. XVI, fig. 7.	*Ostrea flabellula.*
Cardium triforme.	

ECHINODERMATA.

Schizaster beloutchistanensis.	*Clypeaster profundus.*
Eupatagus rostratus.	*Cœlopleurus forbesi.*
Echinolampas, sp.	*Cidaris verneuilli.*

ANTHOZOA.

Trochocyathus burnesi.	*Montlivaltia vignei.*

FORAMINIFERA.

Nummulites garansensis, Pl. XV, fig 10.	*Orbitoides papyracea*, Pl. XV, fig. 7.
N. sublævigata, Pl. XV, fig. 11.	

Although some species pass from the Khirthar, and even from the Ranikot group into the Nari beds, the fauna is chiefly distinct and marks a higher horizon. The most marked change is perhaps in the *Foraminifera*, because they are so abundant and characteristic; whole beds of limestone towards the base of the Nari group being entirely made up of *Nummulites garansensis*, *N. sublævigata* and *Orbitoides papyracea*, the last named frequently of large size, some specimens being two to three inches in diameter; yet every species is distinct from those occurring in the Khirthar group. One of these species of *Nummulites*, *N. garansensis*, is of importance, because it occurs in Europe, as in Sind, in the highest strata characterised by the abundance of the genus, those beds being at the base of the miocene. *Nummulites sublævigata* is peculiar, so far as is known, to India.

Several of the *Mollusca* and *Echinodermata* of the Nari beds also, such as *Siliquaria granti*, *Solarium affine*, *Venus granosa*, *and Clypeaster*

profundus, shew distinctly miocene affinities, and some of these pass up into the Gáj group. But at the same time there are so many eocene forms present, such as *Natica patula*, *N. sigaretina*, *Ostrea flabellula*, *Voluta jugosa*, &c., that it is somewhat difficult to decide to which subdivision the Nari beds should be assigned. They may, perhaps, occupy an intermediate position, similar to that of the oligocene of continental geologists.

Gaj group.—Upon the Nari group, almost throughout Sind, there is found resting a mass of highly fossiliferous limestones and calcareous beds, usually more or less shaly, always distinctly stratified, and easily distinguished from the limestones of the older tertiary formations by the absence of nummulites. A superb section of the strata forming this group is exposed on the banks of the Gáj river, the only stream which cuts its way through the Khirthar range, and in the neighbourhood of which, west of the range, the fine section of lower tertiary and cretaceous beds already noticed is exposed. From this river the present group derives its name.

On the eastern flanks of the Khirthar range in Upper Sind, the Gáj group forms a conspicuous ridge, the hard dark-brown limestone bands near the base of the formation resisting the action of denudation far more than the soft sandstones of the Nari beds, and rising every here and there into peaks of 1,000 and 1,500 feet, or even more, escarped to the westward, and sloping to the east; Amru, the highest summit of the Gáj ridge, being 2,700 feet above the sea. Still, the limestone bands, although so conspicuous, are subordinate, the greater part of the group consisting of sandy shales, clays with gypsum, and, towards the base, sandstones. Many of the bands of limestone appear very constant in position, and may be traced for a long distance; as a rule, they are dark-brown in colour, but one bed is white and abounds in corals and small *Foraminifera* (*Orbitoides*), whilst some of the darker bands contain *Echinodermata* in large quantities.

The uppermost portion of the group is usually argillaceous, being chiefly composed of red and olive clays with white gypsum, and these beds pass gradually into precisely similar strata belonging to the overlying Manchhar group. The passage beds contain, amongst other fossils such as *Turritella angulata*, Pl. XVI, fig. 2, and forms of *Ostrea* and *Placuna*, the following:—

Corbula trigonalis, Pl. XVI, fig. 8.
Lucina (Diplodonta) incerta.
Tellina subdonacialis.
Arca larkanensis, Pl. XVI, fig. 6.

All of these have allies living in estuaries at the present day; *Arca granosa*, a recent representative of *A. larkanensis*, being one of the

commonest and most typical of Indian estuarine mollusca. To these estuarine passage beds further reference will be made presently when the relations of the Manchhar to the Gáj beds are discussed.

The Gáj beds at the Gáj river are very nearly 1,500 feet thick, but they appear to be less developed to the northward in the Khirthar range, and not to be much more than half the thickness named west of Lárkána, where, however, they are nearly vertical, and have probably suffered from pressure. In Lower Sind, the Gáj group, like the Nari, disappears to the eastward of the Laki range, where it is either entirely wanting, or else represented by a thin band containing one of the characteristic fossils, *Ostrea multicostata* (Pl. XVI, fig. 3), at the base of the Manchhar group. There is, however, a very large area of Gáj beds north and north-east of Karáchi, and the appearance of the formation here is somewhat different from what it is in the Khirthar range, for the greater portion of the group consists of pale-coloured limestones, almost horizontal, or dipping at very low angles, and to the east of the Habb valley forming plateaus 400 or 500 feet high bounded by steep scarps, which rise from the low ground of the soft Nari sandstones. A low range of hills, formed of Gáj beds, extends to the south-west, past the hot spring at Magar or Mangah Pir, to the end of the promontory known as Cape Monze, west of Karáchi, and the same beds form the low hills east and north-east of the town, and furnish the materials of which the houses in Karáchi are mostly built. A small island called Churna, in the sea, west of Cape Monze, also consist of Gáj rocks. To the northward the Gáj area of lower Sind extends with very irregular outline to the neighbourhood of Tong and Karchat, almost due west of Hála, and there are several outliers farther north, connnecting the southern portion of the group with the typical outcrop in the Khirthar range. East of Karáchi, also, Gáj beds extend in the direction of Tatta, until they disappear with the other tertiary rocks beneath the alluvium of the Indus. As was shewn in a previous chapter, the Gáj group of Sind appears to be represented in Cutch by a highly fossiliferous belt, containing most of the typical mollusca, echinoderms, &c. It is quite possible that the present group, as well as the Nari, never was deposited in the neighbourhood of Kotri and Jhirak.

It has been already stated that the Gáj beds, throughout the greater portion of the Khirthar range, rest conformably upon the Nari group, although there is a change in mineral character, and that, in lower Sind, the passage from one group into the other is gradual, calcareous bands with Gáj fossils, such as *Ostrea multicostata* and *Pecten subcorneus*, being found interstratified with the uppermost Nari sandstones. At one place

however, near Tandra Ráhim Khán, west by north of Sehwan, the outcrop of the Gáj beds, here dipping at a high angle to the westward, runs nearly in a straight line across the mouth of a valley, composed of a deep synclinal of the Nari group between two anticlinal ridges of Khirthar limestone. As the Gáj beds do not share the synclinal curve of the Naris, it is difficult to see how the two can be conformable; but an examination of the boundary between the two groups failed to shew any clear evidence of unconformity. There are, however, some places south of Sehwán where the Gáj group overlaps the Nari beds and rests upon the Khirthar limestone, but it must be recollected that the Gáj group is itself overlapped by Manchhar beds in the immediate neighbourhood.

Palæontology.—The following[1] is of course a very imperfect list of the animal remains found in this richly fossiliferous group, only the more important or common forms being noticed:—

CRUSTACEA.

Palæocarpilius rugifer.[2]
Typilobus, sp.
Balanus sublævis.

GASTEROPODA.

Buccinum cautleyi.
B. vicaryi.
Vicarya verneuilli, Pl. XVI, fig. 1.
Turritella angulata, Pl. XVI, fig. 2.

LAMELLIBRANCHIATA.

Kuphus rectus (*Serpula recta*, Sow.).
Corbula trigonalis, Pl. XVI, figs. 8, 8*a*.
Venus granosa, Pl. XVI, fig. 7.
V. cancellata.
Tapes subvirgata.
Cardium anomale.
Astarte hyderabadensis.
Dosinia pseudoargus.
Arca kurracheensis, Pl. XVI, figs. 5, 5*a*.
Arca peethensis.
A. larkhanensis, Pl. XVI, fig. 6.
Pectunculus pecten.
Pecten subcorneus.
P. bouei.
P. favrei, Pl. XVI, fig. 4.
Spondylus tellavignesi.
Ostrea multicostata, Desh., Pl. XVI, figs. 3, 3*a*.

ECHINODERMATA.

Schizaster, sp.
Maretia cf. *planulata.*
Meoma, sp.
Breynia carinata, Pl. XVI, fig. 9.
Echinolampas jacquemonti.
Echinolampas spheroidalis.
Echinodiscus, sp., Pl. XVI, fig. 10.
Clypeaster profundus.
C. depressus, Pl. XVI, fig. 11.
Cœlopleurus forbesi.

[1] The following fossils from the miocene beds of Sind are figured on Plate XVI:—
Fig. 1. *Vicarya verneuilli.*
" 2. *Turritella angulata.*
" 3. *Ostrea multicostata*, Desh.
" 4. *Pecten favrei.*
" 5. *Arca (Paralellopipedum) kurracheensis.*
Fig. 6. *Arca (Anomalocardia) larkhanensis.*
" 7. *Venus granosa*, ½.
" 8. *Corbula trigonalis.*
" 9. *Breynia carinata.*
" 10. *Echinodiscus*, sp.
" 11. *Clypeaster depressus*, ½.

[2] Stoliczka: Pal. Ind., Ser. VII, p. 8, Pls. IV, V.

ANTHOZOA.

Pachyseris murchisoni.	*Cladocora haimei.*
Hydnophora plana and other species.	*Mycedium costatum.*

FORAMINIFERA.

Operculina canalifera.	*Orbitoides papyracea.*

The commonest and most characteristic fossils of this group are *Ostrea multicostata*[1] and *Breynia carinata.* There cannot be any question that the Gáj fauna is newer than eocene; some of the species are recent (for instance, *Dosinia pseudoargus* is identical with the recent *D. exasperata,* Chemn.), and it is probable that many others, when they are compared with recent forms more carefully than has hitherto been done, will prove to be the same as living species. Several genera, too, as *Maretia, Breynia, Meoma, Echinodiscus, Cladocora,* and *Mycedium,* are rare or unknown in the older tertiaries, and there is almost a complete disappearance of eocene forms, very few species being common to the Nari beds even. The chief doubt is whether the Gáj should not be considered as upper miocene.

The only mammal yet obtained from the Gáj beds is *Rhinoceros sivalensis*—a species found also in the Siwaliks.

Manchhar group.—The highest sub-division of the Sind tertiary series has been named from a large lake, the Manchhar, a few miles west of Sehwan. The group doubtless represents generally the far better known Siwaliks of Northern India, and it is probable that the upper and lower limits of the two may be the same, but the fossiliferous bands are at different horizons.

The Manchhar group of Sind consists of clays, sandstones, and conglomerates, and attains in places a thickness of but little, if at all, less than 10,000 feet on the flanks of the Khirthar range. Although it is difficult to draw an absolute line between the sub-divisions, the whole group may be divided, wherever it is well exposed, into two portions; the lower consisting mainly of a characteristic grey sandstone, rather soft, moderately fine grained, and composed of quartz, with some felspar and hornblende, together with red sandstones, conglomeratic beds, and, towards the base, red, brown, and grey clays; the latter, however, being much less largely developed than in the upper sub-division. The conglomeratic beds chiefly contain nodules of clay and of soft sandstone, apparently derived from beds precisely similar to those of the Manchhars themselves; so far as has been observed, these conglomerates do not contain fragments derived from the older tertiary rocks, no pebbles either

[1] It is not quite certain whether this species is identical with the European form, but it is certainly the shell figured by Messrs. D'Archiac and Haime. There is another species known by the same name and found in triassic beds in Europe.

of the characteristic Gáj limestones or of the still more easily recognised nummulitic limestone of the Khirthars having been noticed in the beds of the lower Manchhars, although both abound in the upper strata of the group. These conglomeratic beds of the lower Manchhars are frequently ossiferous, the bones and teeth contained in them being, however, usually isolated and fragmentary.

The upper Manchhar sub-division, where it is best seen, on the flanks of the Khirthar range, west of Lárkána, is thicker than the lower, and consists principally, towards the base, of a great thickness of orange or brown clays, with subordinate bands of sandstone and conglomerate. The sandstones are usually light-brown, but occasionally grey, like the characteristic beds of the lower sub-division. The higher portion of this upper sub-group contains more sandstone and conglomerate, and the whole is capped by a thick band of massive coarse conglomerate, which throughout Upper Sind forms a conspicuous ridge along the edge of the Indus alluvium. This conglomerate contains numerous large pebbles of nummulitic and Gáj limestone, together with fragments of quartzite and other rocks of unknown origin. Throughout the conglomeratic beds of the upper Manchhars, pebbles of nummulitic limestone and of the brown Gáj limestone occur, shewing that these older tertiary beds must have been upheaved and denuded in the later Manchhar period, although there is a complete passage between the Gáj beds and the lower Manchhars.

There appears, however, good reason for supposing that some disturbance of the older rocks took place before the deposition of the lower portion of the Manchhar group. To the east of the Laki range the Manchhar beds, themselves disturbed, rest unconformably on the Khirthar group, the beds of which are vertical in many places, so that it is manifest that the Khirthars had in this locality been upheaved before the deposition of the Manchhars. The presence in this locality of the lower portion of the latter group appears to be proved by the occurrence of teeth and bones of the same mammals as are found in the lower Manchhars elsewhere.

It is evidently far from improbable that the Manchhar group of Sind should be sub-divided into two distinct groups, the upper being perhaps the equivalent of the typical Siwaliks. Only a few fragments of bones, too imperfect for determination, have, however, hitherto been found in the upper Manchhars, so that no clue to the age of the sub-division is afforded by fossil remains. There is also a possibility that the coarse conglomerate capping the whole tertiary series should be classed apart from the underlying beds, although it appears to pass into them. The only reason for

distinguishing the upper conglomerate, apart from its great coarseness and thickness, is that it, and it alone, exhibits some slight connection in its development with the existing features of the country; at least the conglomeratic band appears to be much thicker at the spot where it is traversed by the Gáj river than it is to the northward or to the southward, and this increase in thickness may be due to an accumulation of pebbles brought down by a stream which occupied in upper Manchhar times the same position as the Gáj now does. A similar increase in the development of conglomerate near the course of the present rivers will be noticed in a subsequent chapter in the case of the Sub-Himalayan Siwaliks. It is, however, manifest that a great part of the disturbance which has caused the elevation of the Khirthar range is of later date than the Manchhar conglomerate, because that conglomerate has been tilted up at high angles, and appears to dip conformably with the older tertiary rocks. Nevertheless it is true that, as has been shewn in the last paragraph, there must have been some change of level before the Manchhars were deposited, and it is also true that there is in places an apparent passage from the upper Manchhar conglomerate into the gravels of the slope, on the edge of the alluvium, but the latter may simply be due to the reconsolidation of pebbles derived from the conglomerate itself; and if the amount of disturbance in the interval between the upper and lower Manchhar periods was considerable, the evidence of such a break should be more conspicuous than it is. On the whole, it appears evident that the great period of disturbance which terminated the tertiary epoch in Sind commenced during the deposition of the Manchhar beds, or probably even earlier, but that far greater changes took place after the highest Manchhar strata had been deposited than during the period of their deposition.

In one case a few estuarine fossils were found, near the Nari stream, in a Manchhar bed 300 or 400 feet above the base of the group. The only form recognised was *Corbula trigonalis*, already mentioned as characteristic of the estuarine passage beds between Gáj and Manchhar. With this exception, and that of some rolled oyster-shells possibly derived from a lower formation, no marine or estuarine fossils have been observed in the Manchhar beds of Upper Sind, above the passage beds at the base of the group, and there appears every reason to believe that the group is of fluviatile origin. The form of the pebbles in the conglomerate of the upper Manchhars is that of stream-worn, and not that of sea-worn fragments; they approach an oblate rather than a prolate spheroid. Still the amount of rounding is such as could only have been produced by a rapid stream.

In Lower Sind, however, there is a very considerable intercalation of marine or estuarine beds with the Manchhars, and this evidence of deposition in salt water increases in the neighbourhood of the present coast. Around Karáchi, beds of oysters, and sometimes of other marine or estuarine shells, are found not unfrequently interstratified with the Manchhar group. There is also some change in mineral character, the sandstones becoming more argillaceous and being associated in places with pale grey sandy clays and shales. The passage into the Gáj beds is very gradual, calcareous bands with Gáj fossils, such as *Ostrea multicostata* and *Pecten subcorneus*, being found some distance above the base of the Manchhar group.

Although, on account of the change in mineral character, there is, except in the neighbourhood of the coast, no difficulty in drawing a line between Manchhar and Gáj beds, everything tends to shew that there is no break in time between the two, the lower portion of the upper group being an estuarine or fluviatile continuation of the underlying marine beds. But the great thickness of the Manchhar group in Upper Sind alone would suffice to prove that a considerable period of time must have elapsed during the deposition of this formation, and it is far from improbable that the lower Manchhars may be upper miocene, whilst the upper Manchhars are pliocene.

The Manchhar beds extend along the edge of the alluvium, and form a broad fringe to the Khirthar range, throughout Upper Sind, from west of Shikarpur to the Manchhar Lake, but the breadth of the outcrop varies greatly, being as much as 14 miles where broadest west of Lárkána, and diminishing both to the north and south. As already noticed, the Manchhars are thickest just where their outcrop is widest, but the breadth of the area occupied by them is not due simply to their vertical development, but chiefly to their forming a synclinal and anticlinal roll before disappearing beneath the alluvial plain; whereas in other parts of the range the same beds are exposed in a simple section, all the strata dipping to the westward. To the north the section is complicated by faults, but to the south the thickness of the Manchhar group diminishes greatly, and west of Sehwan, near Tandra Ráhim Khán, although both upper and lower sub-divisions of the group are developed, and the uppermost conglomerate is exposed, the whole thickness of the Manchhar strata cannot be much more than about 3,000 feet. The Manchhar beds are seen west, south, and east of the Manchhar Lake; they are well developed, and occupy a large plain to the east of the Laki range, and west of the nummulitic limestone tract near Kotri and Jhirak; they reappear in many places in the different synclinal valleys to the west of

the Laki range, and they occupy a considerable tract of country east and north-east of Karáchi. But throughout these areas in Lower Sind the rocks are not nearly so well seen as to the northward, the soft sandstones and clays of the Manchhar group having been denuded into undulating plains, covered and concealed in general by the pebbles and sands derived from the neighbouring hills, formed of the comparatively hard older tertiary rocks, and it is far more difficult than it is in Upper Sind to distinguish the different portions of the group, or to form a correct idea of the thickness of strata exposed.

Relations to Makran group.—The Manchhar beds extend along the edge of the sea, west of Karáchi, almost to the end of Cape Monze, but no representative of this formation is seen for a considerable distance to the westward of the Cape. The few exposures of rocks seen near the shores of Sonmiani Bay are older tertiary, or perhaps cretaceous, and the greater part of the country consists of alluvium; a low cliff near the coast, north of Gadáni, being composed apparently of sub-recent deposits. But west of Sonmiani Bay, in the neighbourhood of Hingláj, a well-known place of Hindu pilgrimage, there are high hills of hard greyish white marls or clays, usually sandy, often highly calcareous, and occasionally intersected by veins of gypsum. With this clay or marl, bands of shaly limestone, dark calcareous grit and sandstone are interstratified, but they usually form but a small portion of the mass, although their greater hardness renders them conspicuous. This marl formation extends for many hundreds of miles along the coast, and is well seen at Rás Malán, Ormára, Pasni, Gwádar, near Jáshk at the entrance of the Persian Gulf, and on the Persian shores of the gulf itself. The headlands of Rás Malán, Ormára, and Gwádar consist of great horizontal plateaus, surrounded by cliffs of whitish marl or clay, and capped by dark-coloured calcareous grit, Rás Malán especially being a table-land rising abruptly to a height of 2,000 feet from the sea. These remarkable rocks have been called the Makrán group [1] from the name usually applied to the littoral tracts of Baluchistán.

The Makrán group is of purely marine origin, and abounds in mollusca, echinoderms, &c., most of the species apparently being the same as those found in the neighbouring seas at present. The collections made at Gwádar, Jáshk, and other places have not been sufficiently compared to ascertain whether any are common to the Gáj beds of Sind, but by far the greater portion are distinct; none of the characteristic Gáj fossils, such as *Ostrea multicostata*, *Breynia carinata*, *Echinolampas jacquemonti*, &c., have been noticed in the Makrán group, and the latter

[1] Rec. G. S. I., V, p. 43; Eastern Persia, II, p. 462.

appears to be of later age than the miocene Gáj beds. Although there is no resemblance between the typical Manchhar beds and the characteristic rocks of the Makrán group, nor, from the widely different conditions under which the two formations must have been deposited, would any similarity in mineral character be probable, some of the soft argillaceous shaly sands in the Manchhar beds near Karáchi closely resemble some similar beds in the Makrán group near Gwádar. As the coast of Baluchistán has never been examined geologically, all that is known of its structure having been ascertained by brief visits to a few points separated from each other by intervals of from 50 to 100 miles, it is uncertain to what extent the rocks of Sind extend to the westward, and whether any representatives of the Gáj group, especially, exist in that direction, but there appears a considerable amount of probability that the marine Makrán group in Baluchistán may represent the fresh-water Manchhars and Siwáliks on the edge of the Indo-Gangetic plain.

Palæontology of Manchhar group.—The only fossil remains of any importance hitherto detected in the Manchhar group are bones of mammalia, and all that have been recognised belong to the lower Manchhars, the upper sub-division of the group, as has already been mentioned, having hitherto furnished only a few bones, in too poor and fragmentary a state of preservation for the species, or even the genera, to be determined. The few estuarine shells which have been found in the lowest Manchhar beds in Upper Sind, and a portion at least of the marine fossils procured from a similar horizon near Karáchi, appear to be Gáj forms, and to indicate a close connection between the lower Manchhars and the underlying group. In places, and especially in the neighbourhood of the Laki range, silicified fossil wood is found in abundance in the Manchhar beds, stems of large trees being of common occurrence. The majority are dicotyledonous, but some fragments of monocotyledons are also found.

The following is a list of the species of *Vertebrata*[1] hitherto identified from the lower Manchhar group: it should perhaps be repeated that the remains are extremely fragmentary, and chiefly consist of single teeth and broken portions of bones. No remains of *Quadrumana, Chiroptera, Insectivora, Rodentia, or Cetacea* have hitherto been found, and the fauna is chiefly remarkable for the prevalence of artiodactyle ungulates, allied to pigs, or intermediate between pigs and ruminants.

[1] These have been named by Mr. Lydekker, Rec. G. S. I., IX, pp. 91, 93, 106; X, pp. 76, 83, 225; XI, pp. 64, 71, 77, 79, &c.; Pal. Ind., ser. X, pt. 2.

MAMMALIA.

CARNIVORA.

Amphicyon palæindicus, Pl. XIX, fig. 4.

PROBOSCIDIA.

Mastodon perimensis, Pl. XVII, fig. 3.
M. latidens, Pl. XVII, fig. 4.
Mastodon (Trilophodon) falconeri.
Dinotherium pentepotamiæ.

UNGULATA.

PERISSODACTYLA.

Rhinoceros palæindicus.
* *R.* sp. near *R. deccanensis.*
Acerotherium perimense.

ARTIODACTYLA.

Sus hysudricus.
* *Hemimeryx*, sp.
* *Sivameryx*, 2 sp.
Chalicotherium sivalense.
Anthracotherium silistrense.
* *Hyopotamus palæindicus.*
* *Hyotherium sindiense.*
Dorcatherium majus.
D. minus.

EDENTATA.

* *Manis sindiensis.*

REPTILIA.

Crocodilus, sp.
Chelonia, sp. indet.
Ophidia, sp. indet.

Species marked with an asterisk have not been found elsewhere. The majority of the genera are extinct; *Rhinoceros, Sus,* and *Manis* being the only living types, and the last named has only been recognised from a single digital phalange, so that the generic identification is far from sufficient. Both *Rhinoceros* and *Sus* existed in miocene times, whilst *Amphicyon, Anthracotherium, Hyopotamus,* and *Dinotherium* are not known to occur in Europe in beds of later date than miocene. The genera *Hemimeryx* and *Sivameryx* are peculiar; both are allied to the Siwalik *Merycopotamus.*

The species found also in the pliocene Siwaliks are *Rhinoceros palæindicus, Acerotherium perimense, Chalicotherium sivalense, Sus hysudricus,* the two species of *Dorcotherium, Mastodon ladidens,* and *Mastodon falconeri;* but as the presence of these forms in the Manchhars is inferred for the most part from fragments, the identifications are by no means quite certain, whilst the general facies of the fauna, the absence of characteristic living forms like *Equus, Bos, Antilope, Cervus,* and *Elephas,* and the presence of several extinct genera not hitherto detected in the Siwaliks, shew that the mammaliferous beds of Sind are of older age than the typical Siwalik strata. It should be recollected, moreover, that the precise horizon at which the Siwalik forms are found is but rarely known with accuracy; that some of the Siwalik strata are as old as the lower Manchhars, if not older, and that a portion at least of the older types of mammals are from

beds low in the Siwalik series. None of the remarkable series of types allied to the giraffes and *Sivatherium,* nor of the peculiar bovine and antilopine forms so characteristic of the Siwalik fauna, have as yet been found in Sind; the only ruminant detected in the Manchhar beds is the miocene *Dorcatherium,* and the place of the more specialised *Pecora* appears to have been occupied by the less specialised even-toed ungulates allied to the pig. While therefore it is probable that some extinct types, such as *Anthracotherium* and *Hyopotamus,* which are not known in Europe above the lower miocene, existed in India at a somewhat later period, together with species which survived till pliocene times, it is evident that the lower portion of the Manchhar group can scarcely be considered of later date than upper miocene. The palæontological evidence is in accordance with the geological, and both shew the close connexion between the lower Manchhar beds and the Gáj group.

Post-tertiary beds.—The post-tertiary formations in the Sind hills are not of sufficient importance to deserve a lengthened description; gravel, sand and clays, brought down by torrents, occupy a large area in the valleys, and frequently form a slope some miles broad, extending from the base of each range of hills, and covering a very large portion of the intervening valleys. The same phenomenon is seen throughout a great part of Western and Central Asia, being more conspicuous on account of the dryness of the climate and the resulting deficiency of forest or dense vegetation; independently, however, of the greater facilities for studying such formations which are afforded by the absence of trees and shrubs, the formation of extensive gravel slopes appears to be characteristic of climates like that of Sind, with a low rainfall, because in such tracts rock detritus accumulates along the bases of hills more quickly than it can be carried away by the streams; the rainfall is sufficient to wash down the disintegrated fragments from the steeper slopes, but not to carry them forward where the fall is more gradual.[1]

The great plain north-east of Karáchi is covered by extensive alluvial deposits, chiefly of gravel and sand; the gravels here, and in many of the valleys in Western Sind, being often consolidated into a hard conglomerate by carbonate of lime derived from the pebbles of limestone, which form the bulk of the detritus. Some oysters of recent species are found in the conglomerates near Karáchi.

Additional notes on Sind tertiary series.—Before quitting the subject of the Sind tertiaries, there are two or three points to which attention may be directed. These points are chiefly of interest with

[1] For further details as to these gravel slopes, see Q. J. G. S., 1873, p. 496; Eastern Persia, II, p. 465; and also Drew, Q. J. G. S., 1873, pp. 445, &c.

regard to the geology of more extensive areas, but the knowledge, gained in the last few years, of the sequence in Sind, and of the peculiarities of the upper mesozoic and tertiary series there exposed, together with the great imperfection of our acquaintance with all the neighbouring regions, renders it desirable that these geological features, although they may not be peculiar to the Sind area, should not be overlooked when the characters of the region are compared with those of other parts of India.

Absence of general breaks below pliocene.—The first of these points is the general conformity of the whole series from cretaceous (probably upper cretaceous) to pliocene. The lowest bed, the hippuritic limestone, passes into the cretaceous sandstones, and these again into the olive shales with *Cardita beaumonti*. The Deccan trap and the Ránikot beds at the base of the eocene period follow in regular and conformable succession, and the break, shewn by the Khirthar limestones resting on the denuded edges of the upper Ranikot beds in the Laki range, is merely local, for a few miles to the south-east the two formations pass completely into each other. At the top of the Khirthar limestones also, although there is a sudden and abrupt change in the fauna, no unconformity has been detected at the base of the Nari group, whilst Nari beds in many places, and especially in South-Western Sind, pass uninterruptedly into the miocene Gáj beds, and there is again a complete passage from the latter into the Manchhar group. In the middle of the Manchhar formation there may be a break proved by some slight indications of unconformity and by the appearance of detritus derived from middle and lower tertiary beds in the upper sub-division, but the unconformity, if any exist, is probably local.

Great post-pliocene disturbance.—Here, however, the sequence ends, and, in the evidence of great disturbance having taken place in Western Sind since the upper Manchhar beds were deposited, there is an abrupt and startling change from the phenomena exhibited on the other side of the Indus valley. We are in fact brought into the presence of one of the great facts which divide with so trenchant a line the geology of the Indian Peninsula from that of neighbouring countries. The eocene nummulitic limestone, even in the middle of the Indus valley around Sukkur and Rohri, never dips at more than 5°, and rarely at more than 1° or 2°; the tertiaries of Cutch, Kattywar and Surat pass upwards almost without a break into the coast alluvium; the laterite of Western India, probably of tertiary age at least, lies undisturbed upon the flat cretaceous basalts; and the difficulty in drawing a line between older and newer forms of laterite—a difficulty so frequently pointed out in the

fifteenth chapter of the present work—alone suffices to shew how destitute of violent disturbance the geological history of peninsular India has been in cænozoic times. It is unnecessary here to do more than refer to the older mesozoic and palæozoic rocks of the Indian Peninsula, but it is a fact that the pliocene beds of Sind and the Himalayas are more disturbed than the ancient azoic Vindhyans of Bundelkhand. The uppermost Manchhar rocks on the edge of the alluvial Indus plain are frequently vertical, and rarely dip at lower angles than 30° or 40°, and it is manifest that the great anticlinal ridges of the Sind mountains have been mainly formed in post-pliocene times.

In the few notes on the physical geography of Sind at the commencement of the present chapter, it was shewn that the ranges of hills in the province are simple anticlinals with paralled axes, all running nearly north and south. This probably proves that the action of disturbance has been unusually simple, and has consisted of a distinct lateral thrust from one direction. The change of direction to the westward in Baluchistán, and to the northward in the Punjab, has been noticed elsewhere.

Alternation of marine and fresh-water beds.—The cretaceous rocks appear to have been marine, with the possible exception of the unfossiliferous sandstones above the hippuritic limestone, but at the base of the Sind tertiary rocks, in the Ranikot beds, proofs of the immediate neighbourhood of land are afforded by the presence of terrestrial plants. It is probable that the thin band of Deccan trap at the base of the Ranikot group was of subaërial origin in Sind as elsewhere, and that the lower Ranikot beds themselves are fluviatile. The upper portion of the Ranikot group, the whole of the Khirthar and the lower Nari beds are marine, and the nummulitic limestone may have been deposited far from land, whilst it is certain that a considerable portion of this limestone formation is too pure to have accumulated in a sea into which sediment in any quantity was poured by rivers or washed from a coast line. But, as has been shewn above, the Khirthar limestone in Lower Sind contains intercalated sandstones and shales, shewing the admixture of detritus derived from land, and the great limestone band itself disappears in the south-western part of the province near the Habb river. The thick upper Nari sandstones, and the still thicker Manchhars have, again, the character of fluviatile deposits, but the intervening Gáj group is marine and in part perhaps estuarine.

Thus throughout the tertiary series of Sind there is evidence of frequent alternations of marine and terrestrial conditions, the last marine beds known being of miocene date. It will be shewn in subsequent chapters

that to the northward, on the flanks of the Himalayas, the tertiary marine beds tend to disappear or diminish, even the nummulitic limestone, the only marine formation which appears to be persistent throughout the greater part of the extra-peninsular area, being much less developed in the Sub-Himalayan ranges than it is in the neighbourhood of the lower Indus valley.

CHAPTER XX.

EXTRA-PENINSULAR AREA.

THE PUNJAB HILLS WEST OF THE JHELUM.

Physical geography and general features — Geological data — General geological features — Rock-groups of Salt Range — Rock-groups of Hazára and the Northern Punjab — Abnormal boundary of upper tertiaries — Azoic and palæozoic rocks of Salt Range, &c. — Salt marl — Purple sandstone — Silurian ? — Magnesian sandstone — Speckled sandstone — Carboniferous — Mesozoic rocks of Salt Range, &c. — Ceratite beds — Pseudomorphic salt crystal zone — Jurassic or variegated group — Cretaceous (neocomian) — Olive group.

Physical geography.—Passing northward from Sind to the Punjab, the physical features of the country at first undergo little or no change. The South-Western Punjab near the Sind frontier consists, like Sind itself, of the alluvial plain of the Indus, bounded to the westward, for the most part beyond the limits of the province, by a range of tertiary hills, and to the eastward by a sandy desert. Farther north the alluvial tract expands into the great plain of the five rivers, the rocky boundary, known as the Sulemán Range, continuing to the westward. A little beyond the thirty-second parallel of north latitude, however, a series of curved hill ranges, of which the most important, between the Indus and Jhelum, is known as the "Salt Range," crosses the province from Shekh Budín, a little north of Dera Ismail Khan, to Jhelum, and to the northward of these ranges, which cross the Indus at Kálabágh, a tract of more or less hilly country extends to the foot of the Himalayas, and of the great mountain ranges between the Himalayas of Western Kashmir and the Hindu Kush. But this tract may again be sub-divided into three high level plains, more or less broken up by ravines, and separated from each other by ranges of hills. The south-eastern plain extends from the Salt Range to beyond Ráwalpindi, and closely approximates in dimensions with the basin of the river Soán, a tributary joining the Indus a little above Kálabágh. This plain is sometimes known as the Potwár or the Ráwalpindi plateau; it extends from the Indus nearly to the Jhelum; it has a superficial area of about 7,000 square miles, and a general elevation of about 1,000 feet above the Indo-Gangetic plain to the south of the Salt Range. The surface is greatly cut up by deep ravines in the soft Siwalik beds, of which almost the whole area is composed. North of this southern plain there is a series of hill ranges

known as Márgalla, Chitapahár, Cherát, &c., which have a general east and west (or east by north to west by south) direction, and connect the Murree and Hazára with the Afridi mountains. These hill ranges traverse the Northern Punjab south of Attock, and repeat, though on a diminished scale, the remarkable curves of the Salt Range and Chicháli or Shingarh hills. North of the Cherát and Afridi hills is the alluvial plain of Pesháwar, and this again is bounded on the north by the hills of Swát and Yusafzai, the geology of which is unknown.

A third plain, more to the westward, of smaller extent than either of the former, exists in the neighbourhood of Bannu (Bunnoo). It is close to the northern continuation of the Sulemán Range, and is bounded to the northward by ranges of hills having a general east and west direction in the Bahádur Khel and Waziri country in Kohát, and to the east and south by the trans-Indus continuation of the Salt Range, known under a variety of names, such as Chicháli or Shingarh, Káfirkot, Shekh Budín, &c., none of which, however, appear to have more than a local value.[1] The Bannu plain comprises about 1,500 square miles; it is about 1,200 feet above the sea, and is drained by the Kurram (Koorum) river and its tributaries.

For the purposes of the present work, the boundary between the Punjab and Himalayan areas will be understood as coinciding with the course of the Jhelum below the junction with the Kishenganga at Muzafirabad, the whole of Hazára, and of the hills around Murree (Mari) being included in the Punjab hill ranges. The circumstance that the valley of the Jhelum, which is also the boundary of Kashmir in this direction, closely corresponds with the important change in the main direction of the ranges from the east-north-east strike prevalent in Hazára

[1] No names are applied to these ranges on the map, and almost every writer employs different terms for them. The ranges in the Punjab are not named by the inhabitants of the country, and such distinctive terms as are commonly used appear to be derived either from the tribes inhabiting the hills, as Waziri, Afridi, &c., from the passes through them, from the country around, or from some local peculiarity, as in the case of the Salt Range.

The following are the names used by various writers for the hills forming the western extension of the Salt Range beyond the Indus. The portion near the river, much curved, but having on the whole an east and west strike for some distance, and then turning southwards and running north and south, is known as the Chicháli, Shingarh or Lowagarh and Surgarh. By one writer these hills are called Kháttak. South of the break made by the Kurram river, there is a double range, the northern or north-western, running north-east and south-west, known as the Batani or Shekh Budín ridge, whilst the parallel ridge to the south-east near the bank of the Indus is variously known as Khasor, Betot, Káfirkot, or Rotta Roh. From west of the peak of Shekh Budín another ridge runs to the north-west and joins the Shekh Budín range to the Sulemán. This minor ridge is known as the Pyzu (Peyzoo) from a pass through it. Most of the ridges named consist of tertiary rocks, but older formations occur in the Chicháli or Shingarh and Káfirkot ranges, and under Shekh Budín peak.

to the north-western direction of the Pir Panjál, justifies the selection of this line for the eastern limit of the Himalayan region.

The plains of the Punjab, so far as they require geological notice, or perhaps, it should rather be said, so far as their geology is known, have already been described in the seventeenth chapter with the rest of the post-tertiary Indo-Gangetic plain. The orographical features of the hills to the north and west of the province are peculiar, but our knowledge of the geology requires many additions to be made to it before these features can be understood. The change in the direction of the ranges, caused by a similar alteration in the strike of the rocks at the Jhelum valley, has just been noticed, but this is only one of several similar abrupt changes in the Punjab hills. Commencing again on the frontier of Sind, the Mari and Bhúgti hills, north of Jacobabad, run nearly east and west, whilst the Sulemán Range, from the Sind frontier to Dera Ismail Khan, runs nearly north and south, like the Khirthar and other mountain chains in Sind. The various ranges of the Northern Punjab are so much curved and twisted, that no general direction can be detected; there is, however, in many parts of them, as in the Eastern Salt Range, and in the Shekh Budín hills, a tendency to parellelism with the east-north-east direction of the Hazára hills. The extraordinary curve of the Salt Range at the Indus may be considered a remarkable instance of folding due to compression, but the cause of so singular a change of direction requires further explanation. In the Punjab hills three distinct lines of strike may be traced: that of the Sulemán Range, running nearly north and south; that of the lower Hazára hills, running east-north-east to west-south-west; and that of the Pir Panjál, running nearly north-west and south-east; but all these chains are, in great part at least, of post-pliocene date, for all comprise pliocene beds, and it is difficult to see any reason for doubting that all are of contemporaneous origin.

Geological data.— Our present knowledge of the various hill ranges varies greatly in accuracy and detail. The Salt Range and the elevated tract to the northward in the Ráwalpindi district, known as the Potwár, together with some of the hills west of the Indus forming the trans-Indus salt region, and extending to the neighbourhood of Kohát and Bannu, have been examined and mapped by the Geological Survey [1]; portions of Hazára and the Murree hills have also been surveyed, but of the remainder of the region very little is known. Of the hills of the Deraját from Bannu southward scarcely any information exists. Some notes on the ranges near the Indus, from Kálabágh to Shekh

[1] Chiefly by Mr. Wynne; portions of the Salt Range, of the Murree hills, and Hazára having also been examined by Dr. Waagen. The Salt Range is described at length by Mr. Wynne: Mem. G. S. I., vol. XIV; an account of Mount Tilla having previously

Budín, have been published by Dr. Fleming.[1] A few observations on the geology of the Shekh Budín hills and neighbouring ranges have also been published by Dr. Costello[2] and Dr. Verchere,[3] but the details in all these cases are extremely meagre and imperfect. The Sulemán Range beyond the British frontier has been traversed west of Dera Gházi Khan by Mr. Ball,[4] and some notes on the Mari and Bhúgti hills to the southward were published many years since by Captain Vicary[5]; whilst the only information on the northern part of the range is comprised in some brief notes by Dr. Fleming[6] and Dr. Stewart.[7]

General geological features.—So far as is at present known, the Mari and Bhúgti hills and the Sulemán Range are principally, like the Khirthar and other hills of Sind, composed of tertiary beds, amongst which nummulitic limestone and the conglomerates, sandstones and clays of the upper tertiaries (Manchhar or Siwalik) are the most conspicuous rocks. In the northern part of the Sulemán hills, however, older formations appear, some of them metamorphic. The Shekh Budín and Chicháli or Shingarh hills, west of the Indus, are a continuation of the Salt Range, and contain to a great extent the same rocks, but, as already remarked, they are very imperfectly known. In the Salt Range there is a remarkable series of formations, from older palæozoic to later tertiary, many of them fossiliferous, the oldest rocks being found along the southern base of the range, and all the beds, despite much irregular disturbance, having a general northerly dip. Here the contrast

been published: Rec. G. S. I., III, p. 81. The various descriptions by previous observers are noted in Mr. Wynne's memoir: of these the most important were the reports by Dr. Fleming: J. A. S. B., XVII, 1848, Pt. 2, p. 500, and XXII, 1853, pp. 229, 333, 444. The trans-Indus salt region was described: Mem. G. S. I., XI, pp. (105)—(330); the Kharian hills, south of the Jhelum, Rec. G. S. I., VIII, p. 46; the neighbourhood of Mari (Murree) hill station, Rec. G. S. I., VII, p. 64; and the tertiary rocks of the upper Punjab, Rec. G. S. I., X, p. 107,—all by Mr. Wynne. Some details were also given: Q. J. G. S., 1874, p. 61; 1878, p. 347; and Rec. G. S. I., III, p. 73; VI, p. 59. The geology of Mount Sirban, close to Abbottabad in Hazára, was described by Dr. Waagen and Mr. Wynne: Mem. G. S. I., IX, pp. (331)—(350); whilst Dr. Waagen separately gave an account of a section near Murree: Rec. G. S. I., V, p. 15; and of forms of *Ammonites, Ceratites,* and *Goniatites* from carboniferous rocks: Mem. G. S. I., p. (351). The fossil collections made by Dr. Fleming and Mr. Purdon in the Salt Range were described by Mr. Davidson: Q. J. G. S., 1862, p. 25; and Prof. de Koninck: Q. J. G. S., 1863, p. 1. The only other important contribution to the geology of the Punjab is by Dr. Verchere: J. A. S. B., XXXV, Pt. 2, pp. 89, 159; XXXVI, Pt. 2, pp. 9, &c.

The present and the following chapter are chiefly compiled from data furnished by Mr. Wynne's papers, except where the contrary is stated.

[1] J. A. S. B., XXII, 1853, pp. 259, 261, 268, &c.

[2] J. A. S. B., XXXIII, p 378.

[3] J. A. S. B., XXXIV, Pt. 2, p. 42; and map, J. A. S. B., XXXVI, Pt. 2.

[4] Rec. G. S. I., VII, p. 145.

[5] Q. J. G. S., 1846, p. 260; Geol. Papers on Western India, p. 521.

[6] Q. J. G. S., 1853, p. 346.

[7] J. A. S. B., XXIX, p. 314.

so frequently noticed between the peninsular and extra-peninsular areas of India is very strongly marked; although the Korána hills,[1] apparently composed of the Arvali transition beds, are but 40 miles distant to the south-east, not a single formation, out of the ten pre-tertiary groups distinguished by Mr. Wynne amongst the rocks of the range, has hitherto been clearly identified with any formation in the peninsular area, and the Salt Range tertiary beds are only represented, as already noticed, in Western India. At the same time the peninsular formations contrast much more strongly with the marine palæozoic and mesozoic strata of the Western Salt Range than with the unfossiliferous sandstones in the eastern part of the hills, and there is not only a gradual passage in the range itself from west to east, from a distinctly marine facies to one more nearly resembling that of the Vindhyan and Gondwána series of the peninsula, but there is still a possibility that some of the peninsular formations may be identified with those of the Eastern Salt Range. All that can be said is that no such identification has hitherto been made. Dr. Waagen suggests[2] that the Salt Range marks the passage from the extra-peninsular to the peninsular type of rocks, and these hills may consequently be on the margin of the ancient land area, of which the Indian Peninsula formed a portion in palæozoic and mesozoic times.

Rock-groups of Salt Range.—The following is a general list of the rock-groups found in the Salt Range in descending order[3]:—

	European equivalents.	*Name.*	*Character of rocks.*	*Approximate thickness, in feet.*
TERTIARY.	PLIOCENE	14 Upper Siwalik	Conglomerates, drab and pink clays	300 to 2,000
	MIOCENE (?)	13 Lower Siwalik[4]	Grey sandstones and red clays, with mammalian bones	1,200 to 7,500
		12 Náhan ?	Greenish-grey sandstones	600 to 1,000
	EOCENE	11 Nummulitic	Pale limestones, with nummulites and other fossils	400 to 600
			White sandstones, shales, and red and grey clays, with lignite and gypsum	150 to 300

[1] *Ante*, p. 52.

[2] Denkschr. K. Akad. Wiss. Wien., 1878, p. 8.

[3] Wynne, Mem. G. S. I., p. 69. The Salt Range was mapped geologically by Mr. Wynne, but Dr. Waagen spent part of a season in examining the rocks and added to the accurate determination of the fossiliferous formations, besides distinguishing the triassic group, which had previously only been separated on lithological characters. Unfortunately, his health having failed, Dr. Waagen was obliged to leave India without working out the palæontology. He is now occupied in determining the fossils.

[4] As will be shewn subsequently, it is possible Nos. 12 and 13 of the list, the "lower Siwalik" and "Náhan" of Mr. Wynne's classification, should rather be classed as middle Siwalik (pliocene). See foot-note, p. 512.

	European equivalents.	*Name.*	*Character of rocks.*	*Approximate thickness, in feet.*
MESOZOIC.	CRETACEOUS	10. Olive group	Olive, reddish and white sandstones, slightly calcareous beds and black clays with boulders, slightly fossiliferous	150 to 350
	JURASSIC	9. Variegated group	Red, white and variegated sandstones, yellow and grey limestones and marls, fossiliferous	200 to 500
	TRIASSIC	8. Pseudomorphic salt crystal group.	Red and pale-coloured flaggy sandstones with blood-red clays or shales, unfossiliferous	50 to 500
		7. Ceratite beds	Grey limestones, calcareous sandstones, and grey marls, weathering greenish, fossiliferous	120 to 250
	CARBONIFEROUS	6. Carboniferous limestone.	Grey and magnesian limestone, calcareous sandstone, and argillaceous beds, highly fossiliferous	300 to 500
AZOIC AND PALÆOZOIC.	?	5. Speckled sandstones	Speckled, reddish and white sandstone, red and lavender clay, unfossiliferous	250 to 450
	?	4. Magnesian sandstone	Light-coloured magnesian sandstone and shales, unfossiliferous	150 to 250
	SILURIAN ?	3. *Obolus ?* beds	Black shales with glauconitic calcareous layers and sandy bands, fossiliferous	30 to 150
	?	2. Purple sandstones	Deep purple sandstones, unfossiliferous	250 to 450
	?	1. Salt marl	Red gypseous marls with thick beds of rock salt and thin dolomitic layers	800 to 1,500 base not seen.

Scarcely any of these groups, except the salt marl at the base, and the later tertiary beds at the top of the series, are found throughout the range, although the nummulitic limestone is only absent in a few localities at each end. No. 2 of the preceding section, the purple sandstone; No. 3, the black silurian shales; No. 4, the magnesian sandstone; No. 8, the red sandstones and shales, with pseudomorphs of salt crystals; and No. 10, the olive group, are all wanting in the western part of the range: whilst No. 5, the speckled sandstone; No. 6, the carboniferous limestone; No. 7, the triassic limestone; and No. 9, the jurassic group, are absent to the eastward. Similar differences may exist between the Western Salt Range and the continuation west of the Indus; one formation, the necomian, is certainly found to the westward, but not east of the river. The important distinction, however, is the prevalence of marine fossiliferous rocks in the western, and of unfossiliferous beds in

the eastern part of the range, all the principal fossiliferous formations below the olive series, the carboniferous, triassic and jurassic beds, being restricted to the western portion of the area.

Rock-groups of Hazara, and the Northern Punjab.—The rocks to the northward in Hazára and near Murree, and in the hills of the Northern Punjab near Attock and Peshâwar, differ to a very great extent from the Salt Range beds. Although the formations are, in many cases, of similar age, marine eocene, cretaceous, jurassic and triassic rocks being found in both areas, there is a marked distinction, both in mineral character and in fossils, between the mesozoic rocks in Hazára and those in the Salt Range, and no connexion has been traced between any of the palæozoic groups. The nummulitic limestone also exhibits differences in the two regions. The mesozoic rocks of the Northern Punjab are more closely connected, both by mineral character and fossils, with the comparatively distant trans-Himalayan beds of Zanskár, Rupshú and Spiti, than with the strata of the Salt Range.

The following are the formations found in the extreme north of the Punjab:—

	European equivalents.	*Name.*	*Character of rocks.*	*Approximate thickness, in feet.*
TERTIARY.	EOCENE	Nummulitic	Limestone, chiefly dark-coloured, and shales; some carbonaceous shales locally near the base	1,700 to 3,000
MESOZOIC.	CRETACEOUS	———	Thin-bedded limestones, unfossiliferous	60 and upwards ? 300
			Sandy and rusty limestones, fossiliferous	20
	JURASSIC	Gieumal beds, Spiti shales, &c.	Sandstones, &c., poorly fossiliferous	30
			Limestones, fossiliferous	10 to 100
			Black shales, sandy beds, &c., fossiliferous	30
	TRIASSIC	———	Limestones, magnesian in part, shales and sandstones, fossiliferous	2,000 or less
AZOIC AND PALÆOZOIC.	INFRA-TRIASSIC	———	Siliceous and dolomitic breccia, shales, sandstones, unfossiliferous.	
	TANOL (TANÁWAL) GROUP	———	Quartzites, conglomerates, slates, schists and magnesian limestones, unfossiliferous.	
	SILURIAN ?	Attock slates	Black and grey slates, limestones, &c.	
	?	Schistose beds, quartzites and dolomites.		
	?	Metamorphic and crystalline rocks.		

Abnormal boundary of upper tertiaries.—The boundary between the palæozoic and mesozoic beds, with the hill nummulitic limestone

on the one hand, and the upper tertiaries, including the beds classed as upper nummulitic, on the other, is very marked, and has the appearance of a great crushed fault[1]; it is not clear, however, whether the break is entirely due to faulting, or whether it may not in part be the result of unconformable deposition subsequently to the consolidation of the hill area. One of the chief peculiarities of this boundary is the apparent inversion of the rocks, the newer beds to the south of the junction having commonly a dip towards the north, as if they were inferior in position to the older formations to the northward. The line of fracture is not always simple; occasionally it bifurcates or consists of two or more parallel lines, nor is it an absolute boundary between the two types of tertiary rocks, for the hill variety of the nummulitic limestone is occasionally brought up by faults or exposed in crushed anticlinals to the south of the main line of division, and the newer tertiary beds are similarly met with in places faulted or let in by synclinals to the north of the boundary. The most remarkable occurrence of the hill nummulitic limestone south of the dividing line is in the ridge of Khairi Múrat, south-west of Ráwalpindi, and 10 miles south of the main limit of the formation; whilst the newer tertiary beds are found represented in the Mir Kúlan pass, west of Attock, nearly as far to the north of the junction line, and at Dungagalli, north of Murree hill station. It should, however, be mentioned that the outliers of newer tertiary beds within the area of the hill rocks are not quite so clearly identified as the outlier of nummulitic limestone exposed south of the dividing line.

This discordant junction between the Himalayan rocks and the tertiary formations is not confined to the North-Western Punjab, but is traced throughout the ranges to the east of the Jhelum in Kashmir territory, and thence far to the south-east along the southern slope of the Himalayas. There is, however, this distinction between the boundary in the Northern Punjab and that farther to the south-east, that the eocene formations are found superbly developed as the hill type of nummulitic limestone north of the junction line in the Northern Punjab; whereas to the eastward the rocks on the northern side of the boundary appear, except in the Sirmúr area of the Simla region, to be much older than tertiary. In the Punjab, too, at no great distance to the south of the line, fossiliferous beds of similar age to those found in the Himalayan area are exposed, although the fossil fauna is in some cases different, whilst no similar connection has been traced between the Himalayan rocks and those of the Peninsula generally, except in the

[1] Wynne, Q. J. G. S., 1874, p. 69.

solitary instance of the Damúda beds in Sikhim. One more peculiarity of the abnormal boundary in the Northern Punjab is that the direction here is far more irregular than it is farther to the south-east, and that the boundary line leaves the slopes of the Himalayas to which it is confined to the eastward, and traverses the upper Punjab from east to west.

Commencing at the western end, the abnormal line of junction just described runs along the south of the Afridi hills, and of the Chitapahár and Márgalla ranges north of the Ráwalpindi plain to the Murree hills. So far the direction has been that of the ranges, nearly from west to east, curving to north-east to the eastward. Near the Jhelum, however, the line turns sharply north and runs up the valley of the river to Muzafirabad, whence the boundary turns again sharply to the south-east along the flanks of the Kaijnág range in Kashmir.

A similar abrupt boundary between the older hill rocks and the upper tertiary formations is found along the northern side of the Alps in Europe; and amongst some of the mesozoic rocks there is a singular replacement in the mountain zone, both in the Alps and Himalayas, of formations, occurring in the plains at no great distance, by beds of corresponding age, but differing both in mineral character and fossil fauna. This distinction is most marked in the case of the jurassic rocks,[1] but there is a similar difference in the Trias of the Himalayan and extra-Himalayan regions. The palæozoic beds of the Himalayan Northern Punjab differ also from those of the Salt Range, but the distinction is of a different character, and probably local, for the carboniferous limestone, the only important fossiliferous palæozoic group of the Salt Range, reappears in Kashmir, and the fauna is similar to that of the mountain limestone so widely distributed throughout Europe, Asia, Australia, &c.

Azoic and palæozoic rocks of Salt Range, &c.—Under the circumstances of the case, it appears best to describe separately the palæozoic and mesozoic rocks of the two contrasting areas, and to commence with the southern region. As the rocks of the Salt Range alone are well known, the description of the older non-Himalayan Punjab formations must be almost confined to the area between the Indus and Jhelum, the occurrence of similar beds west of the Indus being noticed wherever their existence has been ascertained.

[1] Waagen, Pal. Ind., Ser. IX, p. 236; Waagen and Wynne, Mem. G. S. I., IX, p. (332); see also Wynne, Mem. G. S. I., XIV, p. 64; and Waagen, Denkschrift M. N. Kl. K. Akad. Wien, XXXVIII, 1878, p. 12.

In the ranges west of the Indus, the greater part of the area is occupied by tertiary rocks, palæozoic beds occurring, however, in the Chicháli range, and forming a considerable portion of the Káfirkot hills. In the southern part of the Sulemán ranges no pre-tertiary formations have hitherto been noticed, but the occurrence of carboniferous limestone west of Dera Gházi Khan has been inferred from the existence of fragments in the beds of streams running from the range. Farther north, in the Mahsud Waziri country, south-west of Bannu, the higher ranges consist of metamorphic and schistose rocks.[1]

Salt marl.—At the base of all the Salt Range sections, throughout the range from east to west, there is found a great thickness of red marl, varying in colour from bright scarlet to dull purple, and containing thick bands of rock salt and gypsum and a few layers of dolomite. The base of this group is nowhere seen, so that the thickness is unknown; all that can be ascertained is that it is not less than 1,500 feet.

The marl itself, which consists of clay, having carbonate of lime and magnesia and a small proportion of sulphate of lime (gypsum) combined, is soft and homogeneous, and the only evidence of stratification, as a rule, is to be found in the intercalated beds of salt, gypsum, and dolomite. In these the strata are frequently seen to be much broken and contorted, although no evidence of disturbance can be seen in the marl itself. Besides the more regular beds, masses of gypsum are frequently irregularly dispersed throughout the marl. Many crystals of quartz and a few of iron pyrites have been found locally in the gypsum. In one locality in the Khewra gorge near Pind Dadun Khan a small quantity of bituminous shale was discovered.

The beds of rock salt to which the group owes its name are very rich, some separate bands being as much as 100 feet in thickness, and there being frequently several thick beds at one locality. Thus at the Mayo Mines of Khewra there are altogether no less than 550 feet of pure and impure salt in the upper 1,000 feet of the salt marl: of this thickness, 275 feet, or one-half, consists of nearly pure salt; the other half, known as *kalar*, being too earthy and impure to be of marketable value without refining. The salt of the Punjab, it should be noted, is transported and sold in the market as it is dug from the mine, without being refined. The beds of salt, so far as they are known, are most abundant in the upper portion of the group, and the principal bands of gypsum overlie the salt beds. The salt bands do not appear to be continuous

[1] Stewart, J. A. S. B., XXIX, 1860, p. 316; Verchere, J. A. S. B., XXXVI, 1867, Pt. 2, p. 18.

over a large area, but owing to the manner in which the outcrops are usually dissolved by rain, and then covered up by the marl, it is impossible to trace the beds. The salt itself is white, grey or reddish, and is frequently composed of alternating white and reddish layers, differing in translucency as well as in colour. Some bands are almost pure, others contain small quantities of sulphate of lime and chlorides of calcium and magnesium. At the Mayo Mines one band has been found, 6 feet thick, composed of a mixture of sylvine (chloride of potassium) and kieserite (sulphate of magnesia, with only one equivalent of water), and the latter salt prevails throughout about 7 feet beneath the sylvine band. Epsom salts (sulphate of magnesia, with seven equivalents of water) are produced when water from the atmosphere is absorbed by the kieserite, and they frequently weather out on the surface, shewing that the magnesian salt is of common occurrence in the rock. Glauberite (anhydrous sulphate of soda and lime) has also been found by Dr. Warth, to whom the discovery of most of the salts mentioned is due.

Owing to the softness of the marl, and to the tendency of harder rocks to slip upon it whenever it is sufficiently saturated with water to destroy its coherence, and also to the salt beds being dissolved by water, the rocks of the Salt Range are broken and mixed up in the most complicated manner, masses of the marl having been squeezed by pressure in places into a position in which they appear to overlie more recent rocks, whilst all the newer formations are cracked and faulted. The detailed geology of the range is consequently very intricate, and it is not always easy to tell whether dislocations of the strata are due to true faults traversing all the beds, inclusive of the salt marl, or whether the displacement is merely due to complicated landslips.

Besides being found from end to end of the Salt Range along the base of the southern scarps, the salt marl is exposed for a short distance beyond (west of) the Indus in the hills behind Kálabágh. The same rock is said by Dr. Verchere (and shewn upon his map) to be found at the northern and southern extremities of the Káfirkot hills (Rotta Roh of Verchere), west of the Indus, and south of Isa Khel, and round the southern base of the Shekh Budín peak, a few miles farther west. Dr. Fleming also [1] mentions the occurrence of red and grey saliferous sandstones under carboniferous limestone at the northern extremity of the Káfirkot range. The salt of the Kohát district is derived from beds of apparently much later date than those of the Salt Range.

In a few places, a volcanic rock, having the appearance of diorite, but much decomposed, is found in the upper portion of the salt marl

[1] J. A. S. B., XXII, 1853, p. 260.

just below the purple sandstone. It occurs in horizontal lenticular layers from a few inches to 6 feet or more in thickness, and contains, in abundance, acicular stellate crystals, much decomposed, but apparently of hornblend (tremolite or actinolite), together with talc, quartz, and calcite; the latter in small cavities. It is not at all certain whether this igneous rock is intrusive or contemporaneous, but its occurrence in lenticular beds is in favour of the latter view.

There can be no reasonable doubt that the salt marl is a sedimentary rock, although its very peculiar appearance has induced some observers to suspect an igneous origin. The red colour, however, due to the occurrence of iron sesquioxide, is a normal character of beds containing salt. The absence of organic remains is also a common peculiarity of saliferous rocks. Whether such formations with their beds of rock salt and gypsum have been deposited in salt lakes under process of desiccation, does not appear to be equally generally admitted.[1] The amount of salt in the beds of the Salt Range is so great, that successive supplies of salt water and repeated evaporation alone could produce the thickness of the mineral found in places.

The geological age of the salt marl and of the next formation in ascending order, owing to the absence of fossils, is somewhat doubtful, but the presence of a bed, probably of silurian age, at a higher horizon, shews that both must be of very ancient palæozoic date.

2. Purple sandstone.— The group next above the salt marl consists almost entirely of sandstone of a dull purple colour, containing carbonates of both lime and magnesia. The lower fifty to a hundred feet are more argillaceous, and perhaps indicate transition from the marl below; in the higher portion of the group bands of clay are rare or absent. Near the top the colour becomes paler.

This purple band is found throughout the eastern part of the range, but it dies out to the westward, or is replaced by an argillaceous conglomerate. No fossils have been found in the present group, which has not hitherto been traced beyond the Salt Range.

3. Silurian (?).—Throughout the eastern portion of the range some blackish sandy shales, of a dull purple colour when dry, overlie the purple sandstones, and although comparatively of small thickness, are well seen in various cliff sections. Sandy or conglomeratic and calcareous bands occur in the group, but the shaly character is predominant. In these shales a species of Brachiopod belonging to the genus *Obolus*, or some allied form, has been found. *Obolus* is a characteristically lower

[1] For a discussion of this question, and references, see Wynne, Mem. G. S. I., XI, p. (141), and XIV, p. 82.

silurian type, but the determination is not sufficiently certain to fix the age of the shale definitely.

4. **Magnesian sandstone.**—The next group in ascending order is also confined to the eastern portion of the Salt Range, and consists, in its typical form, of a calcareous sandstone, containing magnesia, or of a sandy dolomite, (the latter being perhaps the more correct term,) a hard, massive cream-coloured rock, conspicuous on the scarps from its massive character. Associated with the harder beds are light-coloured sandstones, occasionally with oolitic layers or flaggy bands, intercalated with greenish and dark-coloured shales.

To the westward this group becomes chiefly composed of sandstones and shales, and is no longer characteristic. No fossils have been found in these beds.

5. **Speckled sandstone.**—In the Eastern Salt Range the dolomitic beds just noticed are succeeded in ascending order by a bright red argillaceous band, No. 8, and then by the olive beds, No. 10; but to the westward other zones are found to intervene, by far the most important of which is the carboniferous limestone. Beneath this, however, and overlying the magnesian sandstone, there is a group of beds consisting chiefly of light-coloured sandstones, with reddish or purplish specks and patches. With the sandstones, red clays and shales, and some very distinctly marked lavender and purplish or greyish argillaceous and gypseous bands, are intercalated, especially in the higher part and at the top of the group. Some traces of copper in the form of small nodules of copper glance have been discovered in these shales, but these concretions are of rare occurrence. The sandstones are commonly distinguished by the occurrence of small concretionary nodules which project in the form of small knobs from the weathered surface. These beds are in parts conglomeratic, containing pebbles of crystalline rocks, and this conglomeratic character increases to the westward. The speckled sandstone group, although well developed throughout the western part of the Salt Range, is lost near the Indus.

Carboniferous.—With the exception of the few *Brachiopoda* from the supposed silurian shales, the oldest fossils hitherto found in the Salt Range occur in the carboniferous rocks, from which a very rich and characteristic fauna has been obtained. The most prominent beds are grey and yellowish limestones, frequently magnesian, and closely resembling the mountain limestone of the British Isles and other parts of Western Europe in texture, colour, and composition, as well as in organic remains. At the base of the group, shales often predominate, succeeded by reddish and yellowish sandstones with *Spirifer*, remains of fish, &c., the sandstones sometimes containing thick beds of black coaly and sandy

shale. The upper part of these sandstones is fossiliferous,[1] and they are succeeded by limestones with numerous *Cephalopoda, Brachiopoda, Bryozoa, Crinoidea*, &c. The upper strata are again sandy, and sometimes consist of light-coloured sandstones with coaly shales and argillaceous beds intercalated, one thick sandstone bed being crowded with a species of *Bellerophon*. The sections vary in different places; beds of sandstone may occur anywhere, and very frequently the massive grey limestone is found at the base of the group resting upon the uppermost lavender clays of the speckled sandstone group.

The carboniferous formation is wanting in the eastern part of the Salt Range,[2] and appears first in the Nilawán ravine near Kallar Kahár, in the form of coarse, light-coloured yellowish-grey and greenish sandstones with coaly laminæ and a band of sandy calcareous shales. The sandstones contain *Productus spinosus*, and the whole group is but 60 to 70 feet thick, resting on the lavender clays of the underlying subdivision. To the westward the carboniferous beds gradually expand to a thickness of 450 or 500 feet, forming in many places a steep scarp, and maintaining this thickness to the neighbourhood of the Indus. Here, like most of the other rocks, they disappear for a space, but they reappear, according to Fleming, in the Chicháli hills, about 7 miles north of Kálabágh, and may thence be traced along the range to near Mulakhel, a distance of about 25 miles. At this spot they are covered up by newer

[1] The following carboniferous fossils, chiefly *Brachiopoda*, are figured on Plate I; the greater portion are from the Salt Range, several being found also in Kashmir and other Himalayan tracts, and a few being peculiar to the latter:—

Figure 1.	*Spirifer keilhavii.*	*Figure* 8.	*Productus semireticulatus.*
,, 2.	*S. moosakhailensis* ½.	,, 9.	*P. costatus* ½.
,, 3.	*Spiriferina octoplicata.*	,, 10.	*P. purdoni.*
,, 4.	*Athyris subtilita.*	,, 11.	*Strophalosia morrisiana.*
,, 5.	*Retzia radialis.*	,, 12.	*Chonetes hardrensis, var. thibetanus.*
,, 6.	*Camerophoria purdoni.*		
,, 7.	*Streptorhynchus crenistria.*	,, 13.	*Aviculopecten hyemalis.*

[2] According to Dr. Waagen, the carboniferous rocks of the Western Salt Range are represented by unfossiliferous sandstones associated with the magnesian limestone to the eastward. He says (Denkschrift Math. Naturwiss. Class. Kais. Acad. Wiss. Wien, 1878 XXXVIII, p. 8), writing of the palæozoic rocks of the Salt Range generally:—"It is very difficult to trace the separate bands through the various phases of their transformation from west to east, but I have endeavoured to do this at least for the lowest strata of the so-called carboniferous limestone, and have found that this formation, proceeding from west to east, passes, first, into a coarse-grained white sandstone which still contains a very few fossils consisting of rolled fragments of coral; next, into a very coarse conglomerate, with boulders the size of a man's head or larger; and lastly, into a homogeneous greyish-green sandstone without any organic remains, which again appears to be closely connected with Wynne's magnesian sandstone."

rocks, but they are again found well developed in the Káfirkot range, south of Isa Khel (Esakhel). Carboniferous rocks do not appear to have been recognised under Shekh Budín, but they occur to the north-west in the country beyond the British frontier,[1] as fragments of black limestone with *Productus* are found in the river Kurram, draining the southern slopes of the Sufed Koh; and Dr. Fleming found boulders of *Productus* limestone in the streams running from the Sulemán Range as far south as the neighbourhood of Dera Gházi Khan.[2]

The following is a list of the fossils hitherto discovered in the carboniferous limestone of the Salt Range and the neighbouring hills, as determined by Messrs. Davidson[3] and de Koninck,[4] some species considered by those authors as probably from higher horizons having been omitted, as it has been shewn that fossils from triassic, and even from higher beds, had been mixed with carboniferous. Three *Cephalopoda* described by Dr. Waagen[5] have also been added. Species marked *e* are also found in Europe or America.

PISCES.

Saurichthys? indicus.
Acrodus flemingianus.
Acrodus, sp. nov.

CEPHALOPODA.

Orthoceras decrescens.
O. rachidium.
O. vesiculosum.
Nautilus flemingianus.
Goniatites primas.
Ceratites carbonarius.
C. sp. indet.
Ammonites (*Phylloceras*) *oldhami.*

GASTEROPODA.

Macrocheilus avellanoides.
M. depilis.
Bellerophon jonesianus.
Bellerophon orientalis.
B. decipiens.
Dentalium herculeum.

LAMELLIBRANCHIATA.

Solenopsis imbricata.
Pecten crebristria.
Pecten asiaticus.
P. flemingianus.
Anomia lawrenciana.

[1] Verchere, J. A. S. B., XXVI, Pt. 2, p. 21.

[2] Q. J. G. S., 1853, p. 348. The boulders of palæozoic limestone found by Vicary Q. J. G. S., 1850, p. 45, in the streams near Peshâwar are also said by Verchere to have contained carboniferous fossils. See foot-note, p. 500.

[3] Q. J. G. S., 1862, p. 25.

[4] *Ib.*, 1863, p. 1.

[5] Mem. G. S. I., IX, p. (351.)

BRACHIOPODA.

Terebratula himalayensis.
T. subvesicularis.
e *Athyris royssi.*
e *A. subtilita*, var. *grandis*, Pl. I, fig. 4.
e *Retzia radialis*, var. *grandicosta*, fig. 5.
e *Spirifera striata.*
S. moosakhailensis, Pl. I, fig. 2.
e *S. lineata.*
e *Spiriferina octoplicata*, Pl. I, fig. 3.
e *Rhynconella pleurodon.*
Camerophoria purdoni, Pl. I, fig. 6.
e *Streptorhynchus crenistria*, Pl. I, fig 6.
e *Streptorhynchus* do. var. *robustus.*
S. pectiniformis.
e *Orthis resupinata.*
e *Productus striatus.*
e *P. longispinus.*
e *P. cora.*
e *P. semireticulatus*, Pl. I, fig. 8.
e *P. costatus*, Pl. I, fig. 9.
e *P. purdoni*, Pl. I, fig. 10.
P. humboldtii.
e *Strophalosia morrisiana*, fig. 11.
Aulosteges dalhousii.
Crania, sp.

BRYOZOA.

Phyllopora ? cribellum.
P ? haimeana.
Retepora ? lepida.
Fenestella ? sykesi.
F. megastoma.
Polypora fastuosa.

ECHINODERMATA.

Philocrinus cometa.
Poteriocrinus ? sp.

ANTHOZOA.

e *Alveolites septosa ?*
e *Michelinia favosa.*
e *Lithostrotion irregulare.*
e *L. basaltiforme.*
Clisiophyllum indicum.

It has been shewn by Dr. Waagen that *Dentalium herculeum* and *Bellerophon jonesianus* occur at a higher horizon than the other fossils and immediately beneath triassic beds with *Ceratites*, &c. *Strophalosia morrisiana* is a Permian form in Europe, and the *Aulosteges* has Permian affinities rather than carboniferous, but most of the *Brachiopoda* and many of the other fossils are characteristically carboniferous. The occurrence, therefore, of a true ammonite and a ceratite, two forms of *Ammonitidæ* not previously found in palæozoic beds, is very remarkable. It was certainly believed by Dr. Fleming that he had found *Ceratites* together with the carboniferous *Brachiopoda*, but the species of the former genus described from his collections are found in a higher bed, which is really of triassic age. The ammonite and the two ceratites discovered by Dr. Waagen, however, were procured by himself, together with *Goniatites primas*, in the upper portion of the group, from a bed containing several typically carboniferous *Brachiopoda*, including *Athyris royssi*, *A. subtilita*, *Spiriferina octoplicata*, *Streptorhynchus crenistria*, *Productus costatus*, &c.

The triassic beds appear not only to be perfectly conformable to the carboniferous of the Salt Range, but to pass into them, and Dr. Waagen

has suggested that some of the upper carboniferous rocks are really of Permian age.

Mesozoic rocks of Salt Range, &c.,—Ceratite beds.—Immediately above the carboniferous limestone, and so closely connected with it as not to have been distinguished except lithologically until the rocks were examined by Dr. Waagen, there is found in the Salt Range, and probably in some of the hills west of the Indus also, a group of marls, limestones, and sandstones, containing a distinctly triassic fauna. The lowest beds of this group are generally thin limestones with *Ceratites*, succeeded by a conspicuous thick marly zone, weathering of a light greenish colour. This is overlaid by grey sandstone and flaggy limestone layers, passing upwards into hard nodular marls, and a succession of similar beds forms the upper portion of the group. Some of the bands of limestone contain glauconite, and beds of conglomerate occasionally occur. In places the formation is chiefly composed of shales and marls.

Like the carboniferous, the triassic group is only found in the western part of the Salt Range, the eastern limit of the latter being some miles farther west than that of the older formation. Triassic beds are found associated with the carboniferous group from the spot where they first appear south-west of Naoshera to the neighbourhood of the Indus. Of their range west of the Indus very little is known; they certainly occur in the range near Káfirkot, as this is one of the localities whence *Ceratites buchianus* was originally procured,[1] and other species of the same genus were found in the same range by Verchere,[2] but it is not so certain whether the trias is represented in the Chicháli range. Dr. Fleming, however, especially states[3] that the upper limestone of the carboniferous group is more distinct in the Chicháli hills than it is west of the Indus, and the beds now known to be of triassic age were included by Dr. Fleming in the upper portion of the carboniferous.

Owing to the triassic beds of the Punjab having been at first confounded with the underlying carboniferous rocks, the fossils of the former have not been sufficiently distinguished for any list to be given.[4] Ceratites abound, and most of the species, probably all, described by de Koninck—*C. flemingianus, C. murchisonianus, C. hauerianus, C. planulatus, C. lyellianus, C. latifimbriatus, C. buchianus, C. davidsonianus* and *C. lawrencianus*—are from the triassic rocks. Besides the *Ceratites*, which are the characteristic fossils of the formation, species of *Orthoceras, Anoplophora,*

[1] Q. J. G. S, 1863, p. 13.

[2] J. A. S. B., XXXVI, 1867, Pt. 2, p. 221.

[3] J. A. S. B., XXII, 1853, p. 264.

[4] As already mentioned in a previous note, those collected by the Geological Survey have been sent to Dr. Waagen for examination.

Cardinia, Gervillia, Rhynconella, &c., occur in large numbers; the bivalves being especially characteristic of the upper beds. The most remarkable fossil, however, is a species of *Bellerophon*, a genus not known to occur in Europe in rocks of later age than palæozoic.

The ceratite beds are probably about the age of the Bunter (lower trias), whilst a *Myophoria* in the overlying limestone closely resembles a Muschelkalk species. Above this no distinct fossil zone can be recognised until the middle jurassic is reached.

Pseudomorphic salt-crystal zone.—A group of thin-bedded and flaggy sandstones, with intensely red shales and clays, is conspicuous in the eastern part of the Salt Range, resting upon the magnesian limestone, and overlaid by the cretaceous olive shales. Where well developed, the upper portion of the present group is argillaceous, the lower portion, which is of less thickness than the upper, being chiefly composed of flags and sandstone, but there is some variation in the section; in places the lower portion of the group consists of red and variegated clays and shales, and where the band is less developed, it consists mainly of flaggy sandstones. On the surface of the sandstones cubical pseudomorphs of salt crystals abound, and are so characteristic that they serve to distinguish the beds. The band is also remarkable for the bright red colour of some of the clays.

The present group is unfossiliferous or nearly so, only some obscure organic traces of doubtful origin having hitherto been detected in it. Its position in the series is far from certain, for it is nowhere in contact with fossiliferous jurassic, triassic, or carboniferous beds; it rests upon the magnesian limestone, and is overlaid by the cretaceous olive group. Each of the three groups, although they appear to form part of a continuous and conformable series, is well distinguished by mineral character and by relations to the other beds; both the overlying and underlying groups being in fact unconformable on the large scale to the intermediate salt-crystal formation, for the speckled sandstone in the western part of its extent intervenes between the place of the salt crystal beds and the magnesian sandstone, whilst the olive group completely overlaps the salt crystal formation, and rests upon older formations to the westward. The reference of the present group to the trias is consequently but little more than a suggestion, and must be considered as liable to alteration, should further evidence be obtained.

The pseudomorph salt-crystal formation is found from Mount Tilla, near the eastern extremity of the Salt Range, to Makrách, north-west of Pind Dadun Khan, but is wanting at Chambal mountain near Jalálpur. West of Makrách no such band is found, nor are similar rocks known west of the Indus.

Jurassic or variegated group.—The next group in ascending order is again a western formation; it consists of soft white and red sandstones, with grey and yellowish limestones and yellow marls, and is unknown in the eastern part of the Salt Range. The lower beds of this jurassic group rest upon the triassic rocks, and consist of sandstones of varying colour, succeeded in ascending order by limestones, clays, and soft white sandstones; then come bands of hæmatite, several feet in thickness, and thinner layers of golden oolite, precisely similar to the rock of Cutch, and the upper portion of the group consists of coarse brown sandstones, yellow marls, white sandstone and hard grey limestone bands. The sandstones are often conglomeratic, and the limestones are most largely developed to the westward. Small layers and patches of bright jetty coal occur in places towards the base of the group, and west of the Indus near Kálabágh these masses are sufficiently abundant to have been worth extraction for the purpose of supplying fuel to the river steamers, but the supply is small; there is nothing like a seam of coal, and no prospect of regular mining operations being successful. The patches of coal appear to be merely carbonized fragments of drift wood.

The Salt Range jurassic beds are not found east of the neighbourhood of Naoshera; they begin to appear a little farther west than the triassic ceratite strata, and increasing much in thickness continue into the Indus. West of that river the same rocks reappear in the Chicháli hills, where they are well developed and more fossiliferous than in the Salt Range; they are well seen in the Chicháli pass, and extend further to the southward round the curve of the range than the carboniferous limestone does, but they disappear beneath the tertiary rocks about 6 miles south of Mulakhel.[1] They are wanting in the northern portion of the Káfirkot range, but are said by Verchere[2] to be well developed at Shekh Budín. On Verchere's map, too, jurassic rocks are represented as occurring in the southern part of the Káfirkot range and also near Bahádur Khel, north-east of Bannu, but Mr. Wynne was unable to find any in the latter locality, although he searched for them in the place indicated. Fleming mentions that *Belemnites* are brought by natives of the country from the Sulemán Range near Dera Ghází Khan, and Verchere found coral limestone, which he considered probably jurassic, in the Waziri country, west of Shekh Budín.[3]

Until the fossils of the Salt Range jurassic beds are examined in detail, it is not possible to say exactly what members of the jurassic

[1] Fleming, J. A. S. B., 1853, p. 278.
[2] J. A. S. B., 1867, p. 15,
[3] l. c., p. 19.

series are represented. Dr. Waagen has shewn that there is a close connexion between the Salt Range oolitic beds and those of Cutch,[1] but that the Himalayan Spiti shales contain a very different fauna. The Kelloway portion of the Chári beds is distinctly represented in the Punjab, and some of the higher jurassic groups also. *Cephalopoda* are scarce, except west of the Indus, where *Ammonites* and *Belemnites* occur rather more abundantly, especially in the fine section of jurassic beds exposed in the Chicháli pass.

Cretaceous (neocomian).—In the Chicháli pass, north-west of Kálabágh on the Indus, the upper jurassic beds, consisting of dark olive clays and sandstones, with patches of oolitic limestone, pass upward into similar beds of a dark blackish-green colour, containing lower neocomian *Cephalopoda*,[2] and these, again, are capped by 60 feet of massive sandstone, light coloured above, black below. This is the only instance in which beds with a lower neocomian fauna have yet been clearly ascertained to occur in India; upper neocomian *Cephalopoda* have, as already stated, been found in Cutch, and some of the *Ammonites* from Sripermatur were also thought by Dr. Waagen[3] to resemble neocomian species.

Olive group.—So far, there is no well-marked break in the series of mesozoic formations, although several groups may be unrepresented, but the next formation in ascending order is much more abruptly limited below. It is found to the eastward, and consists of sandstones of various shades of dark green, grey, olive, and whitish, olive being the prevailing tint. In the upper part some shaly and carbonaceous bands occur, and in the lower part dark shales, filled with large boulders of crystalline rock.[4]

This boulder conglomerate is an extremely interesting formation, for it affords a second instance in India (the Tálchir group being the first example noted) of the characteristic marks of glacial action being found in ancient deposits. Other conglomerates, sometimes containing fragments of rock of large size, are found at a lower horizon in the Salt Range, but the only instance in which evidence has been detected of

[1] Pal. Ind., Ser. IX, p. 236.

[2] Waagen, Pal. Ind., Ser. IX, p. 245.

[3] Denkschr. K. Akad. Wiss. Wien., l. c. p. 12.

[4] In mineral character, in the occurrence of boulders, and in the evidence of glacial conditions at the period of deposit, there is a curious resemblance between this conglomerate of the Salt Range and the Tálchir group of the Gondwána system (see *ante*, p. 109); and Mr. Theobald, the only geologist with any experience of the Tálchir beds who has examined the Salt Range, noticed the similarity (Rec. G. S. I., X, p. 224).

the boulders having been transported by ice is in the olive group. Mr. Theobald found[1] a rounded fragment of red granite, rather less than a foot in diameter, on the surface of this conglomerate, and apparently derived from it; the block is polished and striated on three faces in so characteristic a manner, that very little doubt can exist as to its having been transported by ice. The parent rock of this and many similar fragments found in the same conglomerate is unknown, no crystalline formation is exposed in the neighbourhood of the Salt Range, and no red granite, like that of which the boulders are composed, is known in the Himalayan region to the northward. Some of the transported fragments are much larger than the specimen already mentioned, and at Narwari, a mile east of the Collector's house at the Mayo Salt Mines of Khewra, one block of red granite occurs 7 feet high and 19 in circumference; another large mass lies in the upper part of the Bághanwála ravine in the eastern part of the Salt Range. The derivation of these two blocks from the conglomerate of the olive group is not, however, certain.

The boulder shales at the base of the olive group are found throughout a considerable area in the eastern Salt Range, but they are not co-extensive with the overlying sandy beds. In the latter, fossils are occasionally found, having for the most part a tertiary facies, but one species of *Ammonites* has been found.[2] Large *Nautili*, *Echinodermata*, corals, and *Terebratula flemingi* are the principal forms occurring. *Cardita beaumonti* occurs, but it is rare.

The olive group is very closely connected with the tertiary beds; it appears to pass up into them, and to be perfectly conformable to them whilst the very irregular manner in which it overlaps various older groups shews it to be unconformable to all of them. Although this formation is only fully developed to the eastward, a thin band is found, extending to beyond the Nilawán ravine, and even farther west, at the base of the nummulitic group, beds occur probably belonging to the same horizon; indeed, Dr. Waagen considers[3] that this group may be traced throughout the range and across the Indus, where it rests unconformably on the neocomian.

It is almost certain that this olive group of the Punjab Salt Range is the same as the olive *Cardita beaumonti* beds of Sind; the similarity in position and mineral character is striking, and some of the fossils are identical.

[1] Rec. G. S. I., X, p. 224. The block in question is in the Geological Museum, Calcutta.
[2] Waagen. MS. notes.
[3] MS. notes.

CHAPTER XXI.

EXTRA-PENINSULAR AREA.

THE PUNJAB HILLS WEST OF THE JHELUM—*(continued)*.

Palæozoic and mesozoic rocks of Northern Punjab — Crystalline and metamorphic — Schistose series — Attock slates — Carboniferous and infratriassic (Tanol group) — Trias (including Rhætic) — Jurassic; Spiti shales — Gieumal sandstone — Cretaceous — Tertiary beds of Punjab generally — Thickness of tertiary series — Distribution of eocene beds — Mari and Bhúgti hills — Sulemán Range near Dera Gházi Khan — Chicháli hills and Salt Range — Kohát district — Salt and gypsum — Clays, limestones, and sandstones above the salt — Northern Potwár and Murree hills — Nummulitic limestone of Northern Punjab or hill limestone — Upper tertiaries, Siwaliks, &c. — Distribution—Palæontology — Post-pliocene deposits of the Northern Punjab — Erratics — Indus floods — Fossil shells.

Palæozoic and mesozoic rocks of Northern Punjab.—Before proceeding to the tertiary rocks of the Salt Range and of the Western and South-Western Punjab, it will be well to notice the few details hitherto recorded concerning the older formations of the Alpine and Northern Punjab, comprising Hazára with part of the Murree hills, the Gandgarh, Márgala, and other ranges to the south-west of Hazára, the Chita Pahár, Attock and Cherat hills near the Indus, and the Afridi ranges to the westward. Of the hills of Yusafzai and Swát, north of the Peshávar plain, scarcely anything is known. All the ranges mentioned are north of the peculiar line of dislocation and inversion, already noticed as the northern limit of the upper tertiaries; and all are composed of rocks, which are closely allied to those of the Himalayas, and are for the most part distinct in mineral structure and in organic remains from the strata of corresponding age in the Salt Range. The rocks of Mount Sirbán, near Abbottabad in Hazára, present in many respects an epitome of the geology of the Northern Punjab, and several of the details in the following descriptions are taken from a study of the rocks at that locality by Mr. Wynne and Dr. Waagen.[1]

Crystalline and metamorphic.—The lowest rocks in Hazára are the syenite, porphyritic granitoid gneiss and greenstones of the Pakli

[1] Mem. G. S. I., IX, p. (331). For additional details of the geology of the Northern Punjab, see Wynne, Rec. G. S. I., VI, p. 59; VII, p. 64; X, p. 126; and Q. J. G. S., 1874, p. 61; also Waagen, Rec. G. S. I., V, p. 15; and Denkschr. Kais. Akad. Wiss. Wien., Math. Naturhist. Kl. 1878, p. 10. A sketch is also given in the Punjab Gazetteer, the details for which were furnished by Mr. Wynne.

valley, Súsúlgali, Agror, &c. To what extent these rocks are metamorphosed sedimentary beds, and whether any or all of them are intrusive, is uncertain. The porphyritic granitoid rock with large twin crystals of felspar bears some resemblance to the central gneiss of the Himalayas. Very little more is known of these formations than that they occupy large areas in Northern and North-Eastern Hazára, and that they probably extend thence to the westward. They are a continuation of some of the crystalline rocks forming the axis of the Pír Panjál.

Schistose series.—Between the crystalline rocks and the Attock slates in Hazára there is found an immense thickness of quartzites, dolomites, and schistose beds passing down into gneiss. These rocks apparently rest upon the Attock slates, but the dip seen may be an inversion. They occupy the greater portion of North-Western Hazára and extend down the Indus valley below Turbela. Neither the crystalline nor schistose formations of Hazára extend into the other hills of the Northern Punjab within the British boundary, but both are doubtless continued in the mountains of Yusafzai.

Attock slates.—The next formation has a much wider range. It consists of dark-coloured slates with limestones, some sandstones, and a few intrusions and perhaps contemporaneous beds of basic trap intercalated. These rocks are particularly well seen in the hills on the Indus south of Attock, and have consequently received the name of Attock slates. They are generally remarkable for their dark colour; they are irregularly cleaved, and seldom, if ever, afford good slates for roofing or similar purposes, although their thinly laminated layers are sometimes employed. The limestones vary in texture, being sometimes compact, and occasionally brecciated; they are often altered, and many are dolomitic. They are not often crystalline, although a conspicuous band of sub-crystalline white marble belonging to the present formation extends for some distance along the southern face of the Attock or Mirkulán hills and reappears in the Gandgarh range. The only fossils yet obtained are too obscure for identification, and even such traces of organisms as have been noticed are excessively rare, the slate beds themselves being unfossiliferous.

In parts of Hazára the slates become altered and slightly schistose, as in the neighbourhood of Gandgarh and Haripur. In these hills the typical dark Attock slates are absent or so much altered that they cannot be recognised, the common rock being talcose, silky and schistose from partial metamorphism. Many greenstone dykes and intrusive masses of syenite are found in the schists. In Upper Hazára and Mianjáin, limestones are rare or wanting in the slate series, but they abound in the Gandgarh hills and also near Attock, a few bands of trap being also

found in the Gandgarh range. At Mount Sirbán and around Abbott-abad the group consists of slates of a dark colour, sometimes black or purple, with bands of greenish grey sandstone.

Nothing certain is known as to the age of these slates,[1] except that they must be palæozoic, for they are inferior in position and quite unconformable to the infra-triassic group near Abbottabad in Hazára. They are very probably identical with the slates of the Pir Panjál classed as silurian by Lydekker.[2]

The Attock slates occupy a considerable area in Hazára, and form a broad belt between the tract of crystalline and schistose rocks to the north-west and the newer formations to the south-east; one basin of stratified rocks, including limestone, resting upon the gneissose and schistose series of Northern Hazára, amongst the high mountains near the frontier, may also contain representatives of the present formation. The belt of Attock slates continues to the south-west in the Gandgarh hills and in the east and west ranges forming the Cherat and other hills south of Attock and Nowshera, and extending to the west-ward until the beds are lost near Julozai, beneath the gravels of the Pesháwar plain. To the west of Pesháwar the rocks are unknown, but the same beds may very probably reappear in the Khyber Pass. North of the cantonment of Nowshera, in the plain of Pesháwar, the slates are said to be found near Hoti and Mardán at the base of the Yusafzai mountains.

[1] The suggestion has been repeatedly made by Dr. Waagen, Mr. Wynne and others that the Attock slates are probably represented by beds containing lower silurian fossils in the Khyber Pass. It is not, however, quite certain that the fossils found by Falconer and Vicary in that locality were silurian. The statement that "lower silurian fossils from the Khyber hills were found by Dr. Falconer in the gravel of the Cabul river" was made by Colonel (then Captain) H. H. Godwin-Austen in 1866 (Q. J. G. S., XXII, p. 29). The paper in which this statement was made appears to have been drawn up from field notes without means of access to published information, and no reference is supplied to any original authority. No notice of the discovery of such fossils can be found in Falconer's published writings, and the only original statement in print we have been able to detect is in a foot-note to a paper by Captain Vicary (Q. J. G. S., 1850, p. 45). Vicary himself obtained "a small *Spirifer*, *Orthis* in abundance, a *Terebratula* and some *Polyparia*" from limestone boulders in the water-courses near Pesháwar. In a foot-note he adds: "Dr. Falconer obtained specimens of *Spirifer*, *Orthis*, and other palæozoic forms from these mountains several years ago." Also in a note by Sir R. Murchison, prefixed to Vicary's paper, the discovery of palæozoic fossils is mentioned. Now it is quite possible that the fossils collected by Falconer and Vicary have been examined and their age determined, but as this is not stated, some doubt remains whether the fossils may not have been carboniferous, as they were said to be by Verchere (J. A. S. B., 1867, Pt. 2, p. 21), the *Orthis* being perhaps *Orthisina* or *Streptorhynchus crenistria*, formerly included in the genus *Orthis*. The chief reason for suggesting the possibility of these fossils having been carboniferous, and not silurian, is that carboniferous rocks are known to occur in the Sulemán Range, whilst no fossiliferous silurian beds have hitherto been discovered in that direction.

[2] Rec. G. S. I., XI, pp. 39, 63, &c.

Carboniferous and infra-triassic.—Carboniferous beds have not as yet been detected with certainty in any locality in the Northern Punjab; a specimen of *Productus humboldti* was found close to Hassan Abdál, by Mr. Lydekker, in a loose block of limestone, but with this exception the carboniferous limestone has not hitherto been traced in the Punjab north of the Salt Range and west of the Jhelum, and it is uncertain whence the block in question was derived. The age of the rocks resting upon the Attock slates at Mount Sirbán, near Abbottabad,[1] has not been definitely ascertained; the rocks in question are quite unconformable to the underlying formation; they are overlaid by the triassic group, and comprise two divisions, the lower consisting of red sandstones, red shales and red siliceous dolomites, with, at the base, a red argillaceous breccia full of fragments derived from the underlying rocks; the upper division composed of dolomites only, lighter in colour than the lower beds, often highly siliceous and of considerable thickness. Above these upper dolomites, again, are some quartz breccias, sandstones and shales, all containing hæmatite: these may belong either to the present or the next group.

These beds have hitherto only been noticed at Mount Sirbán and in other places in Hazára; they may of course be in part carboniferous, but no fossils have hitherto been detected in them.

In South-Western Hazára there is an immense thickness of quartzites, slates, conglomerates, sandstones and magnesian limestones, all somewhat altered and quite unfossiliferous. The relations of these beds are obscure; they appear, however, to overlie the Attock slates. For these rocks Mr. Wynne has proposed the name of Tanol (or Tánáwal) group, from a district in the western part of Hazára near Amb. They form a broad belt, in places 8 miles wide from north to south, extending nearly east and west from the neighbourhood of Abbottabad to the Indus, and probably comprise altered representatives of the infra-triassic rocks of Mount Sirbán.

Trias (including Rhætic).—The next zone is chiefly composed of dark limestone, black or grey, distinctly bedded, with thick zones of massive dolomite, sometimes containing numerous laminæ of opaque white quartz, shales, siliceous breccia, hæmatitic clays, and sandstones. Near Abbottabad, where the series is complete, dolomites form the lowest beds, and are followed by thin-bedded fossiliferous limestones; the dolomites are, however, frequently absent. Above the fossiliferous limestones come quartzites and dolomites of considerable thickness, and above these again thin-bedded limestones and slaty shales, fossiliferous, but

[1] Mem. G. S. I., IX, p. (335).

containing different organisms from those in the underlying portion of the group. The lower sub-division contains two characteristic forms, *Megalodon* and *Dicerocardium,* together with *Chemnitzia, Gervillia,* &c., the upper beds contain numerous *Nerineæ,* together with forms of *Neritopsis, Astarte, Opis, Nucula, Leda, Ostrea,* &c. The lower beds are apparently representative of the "Para limestone" or upper triassic of Spiti, and the higher sub-division of the lower Tagling limestone,[1] or rhætic of the same area.

The triassic rocks are well developed in Hazára between Murree and Abbottabad, and extend from the Mochpura mountains to beyond the trunk road, reappearing in the Chita Pahár, but the outcrops are greatly complicated by disturbance and faulting, especially in the neighbourhood of Murree itself and to the northward. Very little is known with certainty as to the extension of triassic rocks to the south-westward, as it is difficult and often impossible to distinguish the different formations in a mass of unfossiliferous contorted limestones and other rocks, comprising representatives of triassic, jurassic and nummulitic beds. The triassic strata are well developed in the spurs from the Hazára mountains east of Hasan Abdál and Haripur. Here the rocks contain but few fossils, although sufficient to enable their age to be determined. The triassic group is also probably represented by massive contorted limestones in the Chita Pahár range and detached ridges to the north along the southern side of the ranges south of Attock and Nowshera, and extending westward into the Afridi hills.

Jurassic,—Spiti shales.—Above the triassic beds there appears to be a break in the series, and in Hazára the next formation in ascending order consists of jet-black shales with more or less ferruginous concretions. These beds have been identified both by mineral character and fossils with the upper jurassic "Spiti shales," of the Himalayan region, but do not appear to be very thick. Amongst the fossils, *Ammonites, Belemnites,* and various *Lamellibranchiata* have been found, some of the most characteristic Spiti species found in the Punjab being *Ammonites* (*Oppelia*) *acucinctus, A* (*Perisphinctes*) *frequens,* and *Belemnites gerardi.* The second and last named are also found in Cutch, though in different zones, the former being known from the Umia group, the latter from the Chári sub-division.

The Spiti shales in Hazára are conspicuous from the contrast they afford to the thick mass of limestones ranging from palæozoic to nummu-

[1] See chapter XXVI, on the Himalayan rocks. The lower Tagling limestone was classed by Stoliczka, Mem. G. S. I., V, p. 66, provisionally as lower lias, but he pointed out that it was the equivalent of the Kössen beds, commonly classed as rhætic. The Para limestone, at first classed as rhætic, was subsequently united to the trias.

litic, and forming the bulk of the rocks. Like the underlying trias, the jurassic beds are greatly broken up by faults and dislocations. The Spiti group is well seen on Chamba hill, north of Murree, and has hitherto been found in no district of the Punjab, except the higher parts of the South Hazára mountains.

Gieumal sandstone.—Above the shales in many places, but not invariably, there is found a thick-bedded sandstone, yellowish-brown and ferruginous externally, but bluish-grey when freshly fractured. Occasionally the Spiti shales are wanting, and the rusty sandstones alone represent the jurassic formation. The sandstone closely corresponds in mineral character to the Gieumal sandstone of Spiti, and has been identified with it by Dr. Stoliczka.[1] As a rule, in Hazára, the present formation is not fossiliferous, but some limestones and earthy beds with a few bands of calcareous sandstone can be traced for a long distance on the spur running west by south from the Murree hills to the north of Ráwalpindi, and traversed by the Grand Trunk Road at the Márgalla pass, and appear to be a continuation of the Gieumal sandstone, or they may represent both this band and the Spiti shales. At the Márgalla pass and in some other places, the rock abounds in *Trigonia ventricosa*,[2] the fossil already noticed as characteristic of the Umia beds in Cutch and of the uppermost jurassic zone near Ellore.

The Gieumal sandstone has not been clearly recognised in the Mount Sirbán section, but may be represented by calcareous sandy beds in the upper portion of the Spiti shales. The sandstone is well exposed north of Murree, in places,—always being, however, much crushed and disturbed.

The Jurassic beds have been traced to the south-west along the Márgalla spur, and again south of the Chita Pahár range, south of Campbellpur, to the Indus, and farther west beyond the Indus near Nilabgash into the Afridi country, where the same beds are seen north of Kohát, but very little is known of the exposures. The Spiti shales may perhaps be chiefly represented by limestones, and the Gieumal sandstone by the beds with *Trigonia ventricosa*, but the characteristic appearance of the Himalayan beds is no longer to be traced in this direction.

Cretaceous.—In Mount Sirbán, resting upon the sandy and calcareous strata at the top of the Jurassic group, there is found a bed, 10 to 20 feet thick, of a different kind of calcareous sandstone, ferruginous and weathering of an orange colour. This bed abounds in fossils, mostly coated with iron oxide, and comprising *Ammonites* of cretaceous forms,

[1] Scientific results of the second Yarkand Mission, Geology, p. 11.
[2] See woodcut, *ante*, p. 261.

all belonging to the *cristati* and *inflati* groups, besides species of *Ancyloceras, Anisoceras, Baculites* and large *Belemnites*. The species have not been determined, but the fauna has a gault facies.

Above the fossiliferous zone there is a group of thin-bedded limestones of grey colour, apparently destitute of organic remains. This may be either cretaceous or nummulitic. It is succeeded by the nummulitic limestone. Cretaceous rocks have hitherto been clearly recognised in only one other locality in the Northern Punjab, north of the Salt Range and Chicháli pass beds; this is close to Kohát, where a band of ferruginous sandy limestone contains some fossils, recognised as of cretaceous age by Dr. Waagen.

Tertiary beds of Punjab generally.—Hitherto, in dealing with the different palæozoic and mesozoic rocks of the Punjab, it has been sufficient to describe isolated outcrops of comparatively small extent; but in treating of the nummulitic limestone and the associated rocks, and to a still greater extent when describing the upper tertiary formations, much larger areas will come under notice, and it will therefore be better to describe each of the two great sub-divisions of the tertiary series, the older tertiary, or eocene, and the newer tertiary, including the representatives of miocene and pliocene formations, throughout the whole Punjab area, commencing at the south. It has already been stated that the miocene marine, or Gáj group of Sind, has not yet been recognised farther north, and although there is very little doubt that the upper eocene Nari group is represented in the Punjab, for some of the characteristic species of nummulites have been brought from Punjab localities, no attempt has yet been made to discriminate the different zones of nummulitic limestone in the northern region by means of fossils. The Ranikot beds, as already noticed, are only known to exist in Lower Sind, but they may be represented by rocks of similar character at the base of the nummulitic limestone in the Salt Range and elsewhere. The only Sind groups which have hitherto been clearly traced to the northwards are the Khirthar or nummulitic limestone proper, and the Manchhar or Siwalik.

Thickness of tertiary series.—The total thickness of the upper tertiary, or Siwalik formation of the Punjab cannot be much less than 15,000 feet, and the Murree beds, into which the upper tertiaries pass, represent about half as much more, so that the whole tertiary series, including the nummulitic limestone and its associated beds, where fully developed, comprises little, if at all, less than 25,000 feet of strata. Of this enormous thickness, all, except the lower 2,000 or 3,000 feet, is destitute of marine remains.

Distribution of eocene beds.—The nummulitic limestone and its associated beds form the higher ranges of the Mari and Bhúgti hills north of the Sind frontier, and extend throughout the Sulemán range, apparently without interruption, from the Sind frontier to Peshá-war. Eocene rocks are said not to occur in the Shekh Budín and other ranges south and south-west of the Bannu plain,[1] but they occupy a very large tract to the northward of the same plain in the Kohát district. They are well developed in the Chicháli and Shingarh range, and they possibly form a great portion of the Afridi hills south of Pesháwar. East of the Indus, the nummulitic group is extensively developed in the Salt Range, and forms the small range of Khairi Múrat south-west of Ráwalpindi. The rocks underlying the Murree beds along the west side of the Jhelum valley belong to the same group, but are poorer in limestone than usual, whilst north of the line of abnormal boundary already mentioned as traversing the Punjáb north of Ráwal-pindi and Kohát, and forming the northern limit of the upper tertiaries, the nummulitic limestone is again largely developed in the Murree and Hazára hills and Chita Pahár, and forms a great band across the province from the neighbourhood of Abbottabad and Murree to the Afridi range south of Pesháwar. In this area the limestone differs from its representative further south, as will be explained presently. A few details of the sections in each area will shew the character of the formation.

Mari hills.—In the Mari and Bhúgti hills north of Jacobabad, the nummulitic limestone forms a number of east and west anticlinal ridges.[2] No lower beds were noticed, and although sandstones rest upon the limestones, it is probable, from the description, that none of them belong to the Nari group, but that they are all Siwalik.

Suleman range near Dera Ghazi Khan.—Not far north of the Mari hills is the section of the Sulemán range near Dera Ghâzi Khan described by Mr. Ball.[3] Here, again, there is no trace of anything which can be identified with the Nari sandstones, the beds resting upon the nummulitic limestone being described as dark-brownish sandstones in beds of no great thickness, alternating with bright red, greenish and grey clays, probably Siwalik. The lowest beds seen in the whole section of the range consist of a great thickness of sandstones and shales with very few fossils, succeeded by from 1,000 to 2,000 feet of massive limestone with

[1] Verchere, J. A. S. B., 1867, XXXVI, Pt. 2, pp. 13–16, and map.
[2] Vicary, Q. J. G. S., II, p. 260.
[3] Rec. G. S. I., VII, p. 145.

nummulites, &c. On the eastern slope of the hills the nummulitic limestones are much mixed with sandy and shaly beds, but a few miles further to the westward the whole band consists of limestone. The main range of the Sulemán consists of the sandstones and shales underlying the limestones. With the shales some very thin layers of coal are occasionally associated, but none are known to exceed about six inches in thickness, and consequently none hitherto discovered are of any commercial value.

The fossils found in the sandstones are all tertiary species,[1] and one, *Ostrea flemingi*, is in Sind a characteristic Ranikot form. There appears good reason for assigning all the beds noticed to the eocene group, the lower sandstones and shales probably representing the lower Khirthars of the Upper Gáj section described in the last chapter. The nummulitic limestone is evidently a continuation of that forming the Khirthar range in Sind.

Chichali Hills and Salt Range.—No full description of the eocene rocks in the northern portion of the Sulemán range has been published, and it will be as well therefore to proceed at once to the Salt Range and its continuation in the curved ridges of Chicháli and Shingarh west of the Indus. A section of the latter range, taken near Sultan Khel, and about 15 miles north-west of Isa Khel, has been given by Dr. Verchere,[2] whilst the Salt Range rocks have been fully described by Mr. Wynne. The section appears much the same throughout, and has a considerable resemblance to that already described in the Sulemán range. There is a bed of limestone several hundreds of feet thick and usually of a light colour, resting upon sandstones, shales and clays, with lignite. The latter pass downwards into the cretaceous olive group, but immediately upon the limestone comes the upper tertiary group, which contains no marine fossils. The Gáj and Nari beds of Sind appear to be unrepresented; there is evidently a break above the nummulitic limestone, and the overlying formation is unconformable, and rests in places upon a denuded surface of nummulitic rocks. The unconformity is also shewn by overlap in several places at the eastern extremity of the Salt Range, and, as already noticed, in the ranges near Shekh Budín, and by the circumstance that the lowest bed of the upper tertiary sandstones sometimes contains pebbles of nummulitic limestone, as for instance near Fadiál, west of Mount Tilla.

[1] The species quoted in Mr. Ball's paper were for the most part only approximately determined.

[2] J. A. S. B., 1865, XXXIV, Pt. 2, p. 42.

The inferior shaly portion of the nummulitic group consists of soft, variegated shales or clays, more or less sandy, with occasionally a pisolitic ferruginous band, resembling laterite, at the base. A similar band is found in a corresponding position in the Sub-Himalayan sections, as will be shewn in the next chapter. Many of the shales and clays are pyritous and decompose readily on exposure, the decomposed shales being burnt and employed in the manufacture of alum. The so-called coal of the Salt Range occurs in the upper part of this lower sub-division, associated with gypseous shales, and is really a lignite of variable purity, found chiefly in thin strings and beds of no great horizontal extent, but occasionally in rather thicker seams, some being as much as three to three and a half feet in thickness. The principal localities are Bhág-anwála, Pid and Samundri. Like most of the tertiary lignites, that of the Salt Range is pyritous, and frequently falls to pieces or takes fire spontaneously when exposed to the air. Similar lignite is found in the Chicháli and Shingarh hills west of the Indus. Beneath the coaly shales are white, red and olive sandstones and clays, occasionally with marls or limestone full of foraminifera, and, in the western Salt Range, a thick band of nummulitic limestones occurs immediately below the beds with lignite.

The main band of nummulitic limestone is usually compact, grey or white, occasionally chalky, the upper portion being generally purer and less mixed with shaly or marly bands than the lower. The whole group is fossiliferous, the nummulitic limestone containing the usual fossils, whilst bands containing nummulites and other foraminifera occur amongst the lower shales and sandstones, but more commonly remains of plants, chiefly dicotyledonous, are found in the latter.

The similarity of the section in the Salt Range with that of the Laki range in Sind is very great; the actual beds are thicker in Sind, but in both localities there are olive shales believed to be of upper cretaceous age at the base, then variegated sandstones, alum shales and clays with plant-remains, lignite and gypsum, followed in ascending order by nummulitic limestone. Further comparison of the fossils will, however, be necessary, before the group beneath the nummulitic limestone in the Punjab can be safely correlated with the Ranikot beds of Sind.

Kohat district.—There is another region in the Upper Punjab where the eocene rocks are well developed, and where they have been fully examined and described; this is in the Trans-Indus salt region of the Kohát district,[1] and the section here exposed, although only a few miles distant from parts of the Salt Range, differs in some important

[1] Wynne, Mem. G. S. I., XI, pp. (101)—(330).

points from that just described. The following is abridged from Mr. Wynne's summary of the rocks exposed :—

		Thickness in feet.
Pliocene and Miocene	*Upper sandstones.*—Soft, grey sandstones, clays and conglomerates	500 to 1,500
	Lower sandstones.—Harder grey and purple sandstones, bright red and purple clays, slightly calcareous and pseudo-conglomeratic bands	3,000 to 3,500
Eocene	*Upper nummulitic.*—Nummulitic limestone and some shaly bands	60 to 100
	Red clay zone, or lower nummulitic.—Red clay, lavender coloured near the top, occasionally with *Nummulites.* The lower portion of the red clays in places is partly or wholly replaced by fossiliferous sandstones, thick greenish clays and bands of limestone all containing *Nummulites*	150 to 400
Eocene?	*Gypsum.*—White, grey or black gypsum with bands of clay or shale	50 to 300
	Rock salt.—Thick beds of salt, almost pure. The base not seen	300 to 700 (? 1,200)

The region examined is the hilly tract north of the Bannú plain and of the Chicháli hills, and extending from the Indus, on the east, to the British frontier. The ground is traversed by a series of east and west ranges, chiefly formed of crushed and broken anticlinals of the nummulitic limestone and the associated rocks.

Salt and gypsum.—The rock salt and gypsum at the base of the tertiary series in the Kohát region are very important and remarkable. The salt consists of a more or less crystalline mass, usually grey in colour, with transparent patches, and never reddish, like the salt of the Salt Range. A few earthy bands occur, but the portion of the whole mass too impure to be worked for commercial purposes is but small, although there is no attempt at refining the salt, which is exported for sale in the form in which it is mined. In some places the uppermost layer is dark-coloured, almost black, and bituminous. The quantity of salt is something marvellous; in the anticlinal near Bahádur Khel alone rock salt is seen for a distance of about eight miles, and the thickness exposed exceeds 1,000 feet, the width of the outcrop being sometimes more than a quarter of a mile. Hills, 200 feet high, are sometimes formed of pure rock salt. As a rule, the salt contains sulphate of lime (gypsum), but none of the potassium and magnesium salts of the Salt Range beds.

Above the salt come gypsum and clays, as in the Salt Range, but the colours, white and grey, are very different, and the whole appearance of both salt and gypsum so distinct from those of the ancient salt marl, that although there is no indication of salt beds at a higher level in the Salt Range itself, and although the outcrop of the salt marl close

to Kálabágh on the Indus is only 18 miles from one of the Kohát rock salt regions at Nundrukki, still as a great series of mesozoic and palæozoic beds intervenes, throughout the Salt Range, between the nummulitic group and the salt marl, whilst in Kohát the former rests with apparent conformity upon the gypsum and salt, it appears probable that the salt-bearing rocks in the Kohát district may belong to a very different horizon from that occupied by the same minerals in the Salt Range series. It is by no means certain that the Kohát salt and gypsum are eocene, but, in the absence of any evidence to the contrary, it appears best to class them with the nummulitic beds immediately overlying them.

Clays, limestones, and sandstones above the salt.—Overlying the gypsum, there is usually found a thick bed of deep red clay, the eocene age of which is proved by the occasional occurrence of nummulites in the upper portion. Sometimes the clay is wanting, and apparently replaced by clays, marls, and limestones of a grey or olive colour, and containing nummulites, but the replacement is not clearly proved. Above the red clay zone come earthy limestones, clays, and shales, with nummulites. The main band of limestone is very much thinner than in the Salt Range, but is as usual massive, pale-coloured, and full of *Nummulites*, *Alveolinæ*, *&c.* The overlying formation, consisting of sandstones and clays, in which dark red and purple colours predominate, exceeds all the eocene beds in thickness, and is probably, like the sandstones and clays overlying the nummulitic limestone of the Salt Range, really of much later age than the limestone on which it rests.

Pebbles of nummulitic limestone are said[1] to be found in the lowest beds of the sandstone, and some reptilian bones, (not determined,) siliceous fossil wood, and a few ill-preserved ribbed bivalve mollusca have been found, but no characteristic organic remains. The beds resemble Murree beds and pass upwards into undoubted newer tertiary (Siwalik or Manchhar) strata of the usual character, the red colours becoming rarer, and the usual drab grey sandstones and orange or drab clays being the prevailing rocks.

Northern Potwar and Murree Hills.—Along the northern side of the Ráwalpindi or Potwár plateau, and up the Jhelum valley for a long distance north of Murree, there runs the line of abrupt boundary, already noticed as intervening between the tertiary formations to the southward, and the Himalayan or Alpine rocks, inclusive of the hill type of nummulitic limestone, to the northward. It is clear that the tertiary beds seen immediately south of the limit in question must be newer than those to the northward, for marine limestones are intercalated with the lowest clays and sandstones seen south of the boundary, and it is difficult to

[1] Wynne, Mem. G. S. I., XI, p. (170).

understand how two totally different formations could have been deposited contemporaneously on the opposite sides of a line along which there is no evidence of any ridge of older rocks to separate the two areas of deposition. Besides, as has already been stated, the hill form of nummulitic limestone occasionally appears a little to the south of the dividing line, being brought to the surface either by faults or anticlinals, and the newer tertiaries are similarly let in by synclinals, whether faulted or not, to the north of the same limit. Such outcrops are at no great distance from the main boundary, and the rocks are so greatly disturbed and contorted that their relations are obscure. In this case, as elsewhere, the additional knowledge of the distribution of fossils in the older tertiary formations afforded by the study of the Sind rocks has not yet been applied to the Punjab region, whilst the complicated disturbance of the rocks and the comparative paucity or bad preservation of organic remains in the latter country render the correlation of the various strata a work of great difficulty.

Perhaps the most interesting section hitherto noticed is that already referred to, occurring in the anticlinal ridge of Khaíri Múrat about 12 miles south-west of Ráwalpindi. Here clays and sandstones with bands of limestone are seen resting conformably upon a massive clearer limestone; the former rocks being evidently identical with the upper nummulitic beds found south of the main boundary, whilst the latter represents the hill nummulitic limestone.

The eocene beds of the Upper Punjab, south of the line of disturbance, consist of sandstones and shales, very frequently of a red colour, and comprising, towards their base, occasional bands of limestone or marl, with nummulites. Associated with the sandstones, some gypseous shales and bands of gypsum are found, but no trace of the Kohát salt. As already stated, these lower tertiary sandstones are cut off abruptly to the north, and it is not always clear whether they rest upon the hill limestone or are faulted against it; doubtless the junction, whether conformable or unconformable originally, has become complicated by faulting and crushing, but the whole line of boundary has the appearance of a gigantic fault. There is a gradual and complete passage, to the south of this line of fracture, from the beds containing nummulites into the upper tertiary Siwalik rocks, with mammalian bones. As will be noticed in the chapter on the Sub-Himalayan area, very similar beds occur at the base of the tertiary series along the southern foot of the Himalayas in the Eastern Punjab, but in this area representatives of the lower nummulitic limestone are shewn to exist by the fossils occurring.

The rocks at the hill station of Murree have been repeatedly described. The station itself is built on grey and purple sandstones and

deep purplish clays, with occasional concretionary bands. These are the Murree beds of Mr. Wynne, and whilst their lower strata may correspond to the Dagshai sub-division of the Sirmur or eocene series in the Simla hills, it is probable that they represent higher groups also, and they may even comprise strata corresponding to all the Sub-Himalayan beds of the Dagshai, Kasauli and Náhan groups between the Subáthu and the Siwaliks proper. It is evident that no definite line can be drawn, either in the neighbourhood of Murree or to the west of Ráwalpindi, between the eocene beds and the newer tertiaries. Immediately north-west of the ridge on which Murree stands, similar grey and red sandstones and shales, underlying the Murree beds, contain bands of nummulitic limestone. These rocks are supposed to represent in part the Subáthu beds at the base of the Sirmur group,[1] but it is probable that the lower portion of the Subáthu group must be older and representative of part of the hill limestone of the Punjab. The bands with nummulites at the base of the Murree beds are traced at intervals from the country west of the Jhelum to the Potwár, and thence to the westward to beyond the Indus.

Hill nummulitic limestone of Northern Punjab.—The "hill nummulitic limestone," as it is frequently called, consists of a great thickness of dark-bluish grey or blackish limestones, with brownish olive shales. The rock is generally fœtid and massive, with nodular bands, but thick zones of pale-grey splintery limestone also occur. Stratification is sometimes distinct, sometimes obscure. Near Dungagali, between Murree and Abbottabad, some red clays are associated with the hill limestone and appear to be interstratified.[2] These Himalayan and North Punjab beds differ from the nummulitic limestone of the Salt Range and Sulemán mountains, and from the Khirthar limestone of Sind, in colour and structure; but it is far from clear how far the distinction is due to the amount of disturbance and pressure experienced by the northern rocks. The intercalation of shales with the limestone takes place also in Lower Sind and Baluchistán. Similar dark-coloured nummulitic limestones are found in Baluchistán, also in a disturbed region, and all the differences hitherto noticed between the hill nummulitic rocks and their representatives in the Salt Range and elsewhere, except colour, might be attributed to the different amount of disturbance that has affected the two regions. No distinctions have been shewn to exist between the organic remains

[1] See next chapter. The tertiary rocks of the Sub-Himalayan ranges are thus classed in descending order :—

1	Newer; Siwalik	Siwalik. Náhan.
2	Older; Sirmur	Kasauli. Dagshai. Subáthu.

[2] Wynne, MS. notes.

found in the two forms of limestone, except that the hill nummulitic beds contain much fewer and smaller organisms.

The hill type of nummulitic limestones forms a broad belt throughout Hazára and the Murree Hills, from the neighbourhood of Abbottabad, past Murree, and along the spurs traversed by the grand trunk road north-west of Ráwalpindi. The same rock forms the greater part of the Chita Pahár Range, and is continued west of the Indus in the Nilabgash and Afridi hills, which are chiefly composed of this formation. This great belt and the parallel band of the Attock slates to the northward are indeed the leading stratigraphical features of the Northern Punjab, the intervening formations being less prominent, although largely developed locally.

Upper tertiaries, Siwaliks, &c.—It will be unnecessary to devote much space to the description of the upper tertiary rocks, since, despite the enormous area covered by them, and their great thickness, they present a nearly uniform character, and differ but little from the rocks of the same age to the southward in Sind, already described in the last chapter, and from the typical Siwalik series of the Sub-Himalayan region, to which the next two chapters will be devoted.

The passage from the lower into the upper tertiaries throughout the Northern Punjab, so far as the ground has been sufficiently examined, is transitional, with the exception of the boundary to the north of the Salt Range, where, as has already been shewn, the upper tertiary rocks rest unconformably on the nummulitic limestones. But even in this area there is an apparent conformity in dip and strike, the bedding planes of the upper tertiary strata being parallel to those of the nummulitic limestone, and it is not quite certain how many sub-divisions of the tertiary series are wanting.[1] Apparently the lower portion, if not the whole of the Murree beds, including the nummulitic bands at their base,—that is, all those rocks classed as older tertiary that are exposed immediately to the south of the line of discordant junction traversing the Northern Punjab,—are unrepresented to the south of the Ráwalpindi plain. It is probable that a similar deficiency of the middle tertiary beds exists on the flanks

[1] The lowest beds resting upon the nummulitic limestone of the Salt Range are considered by Mr. Wynne to represent the Murree beds, but Mr. Theobald, who has identified the same strata with the middle Siwalik group of the Sub-Himalayan region, considers that even the Náhan group is wanting on the northern slopes of the Salt Range. The fact, determined by Mr. Theobald, that an ossiferous band may be traced not 100 feet above the nummulitic limestone, and that amongst the bones discovered in this band are those of *Mastodon latidens* and *Rhinoceros palæindicus*, renders it probable that the beds resting upon the limestone must be either upper miocene or pliocene, and consequently must belong to a higher horizon than that of the Murree beds generally. Still as the limits of the Murree beds are vague and undefined, it is quite possible that strata, elsewhere classed wi h the Murree beds, may be represented north of the Salt Range.

of the Sulemán Range, and it is highly probable that the sandstones and clays resting upon the nummulitic beds in Kohát are also, as already suggested, separated by a considerable break in time from the typical eocenes.

Throughout the Punjab, as in Sind, the upper tertiary rocks consist of a great sequence of sandstones and clays, surmounted in places by a mass of coarse conglomerate of variable thickness. No satisfactory sub-divisions have been established in this series, although it is certain that a large period of geological time is represented; for the mammalian fossils from the lower portion in the Punjab, as in Sind, include much older forms of life, and resemble those peculiar to the miocene of Europe, whilst in the upper beds living genera are common, although the species are extinct.

The transition from the Murree beds to the upper tertiaries or Siwalik series is marked by a diminution in the prevalence of red clays and sandstones, and by the appearance of bright grey sandstones in great abundance. The sandstones become softer, concretionary bands more numerous, and a few pebbles derived from the nummulitic limestone and Murree beds, together with rounded fragments of quartzite and crystalline rocks, make their appearance. Higher in the section the red clays disappear, and are replaced by orange and grey clays, and there is a gradual passage upwards into the massive conglomerates, which form in many places the upper portion of the whole series. The pebbles of these conglomerates appear to have been derived from the same Himalayan rocks as those now furnishing the materials for the gravel and boulder beds of the Punjab rivers, and it is consequently evident that the rivers in the Siwalik period ran from the north, as they do now.

Distribution.—Commencing, like the eocene rocks, at the southern extremity of the area, the upper tertiary beds form several ranges of hills north of the Upper Sind frontier, between the desert plain of Jacobabad and the ridges of nummulitic limestone; and, to judge by Vicary's section,[1] the higher beds reappear in the valleys between the parallel anticlinal ranges of older tertiary limestone, precisely as in Lower Sind. Passing northward along the boundary of the Deraját, the Siwaliks, although forming only a narrow belt on the flanks of the Sulemán Range in the Siri Pass, west of Dera Gházi Khan, comprise two well-marked sub-divisions; of these the upper, consisting of conglomerates and coarse sandstones, 500 to 600 feet thick, rests unconformably upon the lower, composed of sandstones with bright red, greenish, and grey clays, and attaining a thickness of at least 3,000 feet, and probably more.[2] The only sections recorded have been too hurriedly traversed for more details to be determined, and it must remain for the

[1] Q. J. G. S., II, 1846, p. 261. | [2] Ball, Rec. G. S. I., VII, p. 150.

present uncertain whether any of the intermediate groups of Sind are represented on the flanks of the Sulemán Range.

Passing northward along the Sulemán, the belt of upper tertiary beds appears perfectly continuous. The whole of the Pyzú and Shekh Budín ranges are believed to consist of newer tertiary strata, with the exception of the peak of Shekh Budín itself, and all the north-western slope of the Káfirkot range near the Indus is of the same Siwalik formation. A broad tract to the west of the Bannú plain, the Waziri country north of Bannú, and the western slopes of the Shingarh Range are similarly composed, so that the newer tertiary beds entirely surround, and probably underlie, the Bannú plain.[1] North and north-east of this the upper tertiary formations cover a large portion of the Kohát district west of the Indus, and nearly the whole of the great Ráwalpindi plateau to the east of the river, being thrown throughout into a series of great wave-like undulations, the anticlinal and synclinal axes of which have a general east and west direction. Older rocks appear to a large extent in the anticlinal ridges west of the Indus, more sparingly to the eastward, and to the north the upper tertiary area is bounded by the Murree and upper nummulitic beds south of the great line of dislocation.

Palæontology.—It is unnecessary to enter into any detailed account of the organic remains, almost entirely vertebrate, found in the newer tertiaries of the Punjab, because a large number of the same species have also been discovered east of the Jhelum, and it will be better to deal with the Siwalik fauna as a whole. Owing to the similarity of the beds composing the upper tertiary series throughout, and the complicated disturbance which the rocks have undergone in many places, it is very often impracticable to determine the precise horizon at which any particular fossiliferous beds occur, and with a large proportion of the bones hitherto collected, the original locality has been imperfectly recorded. It is therefore impossible to draw up anything like a trustworthy list of the species found in any sub-division of the newer tertiary series; all that is known with certainty is that the majority of the bones found in the Punjab are from the higher portion of the strata.

In one case only has the peculiar miocene fauna of the Sind Lower Manchhar beds as yet been detected in the Punjab, and in this case the exact locality is unknown, but it was in the neighbourhood of Kushálghar, 40 miles south of Attock.[2] Remains of *Mastodon, Dinotherium pentepotamiæ, Listriodon pentepotamiæ, Rhinoceros, Merycopotamus, Dorcatherium, Sanitherium schlagintweitii,* and *Amphicyon palæindicus*

[1] These details are from Verchere's map, J. A. S. B., 1867, XXXVI, Pt. 2, and from the Atlas sheets of the Great Trigonometrical Survey.

[2] Lydekker, Rec. G. S. I., IX, p. 92. The fossils were first noticed by Falconer, Pal. Mem., I, p. 415.

were found. There can be no question that the beds yielding the above fossils must be at a lower horizon than those from which the bulk of the Siwalik fauna has been procured. It is, however, far from improbable that some of the supposed Siwalik forms come from the same lower horizon, as certain species belong to older forms of life than the majority of the Siwalik vertebrates.

Post-pliocene deposits of Northern Punjab—On the great plains of Ráwalpindi (the Potwár), Bannú, and Peshávar, extensive deposits of gravel, sand and silt exist. Little is known about later deposits in the Pesháwar and Bannú plains, but those of the Potwár present some features of interest. The surface consists of an alluvial, rather light-brown clay, often containing kunkur, and passing in places into fine silt. Beneath this alluvial deposit there is a mass of gravels and sand, sometimes enclosing boulders of large size. The boulders are not, however, confined to the pebble beds; many have been observed imbedded in fine silt, and this circumstance, together with the great size of many of the blocks found, and the distance to which they have been transported, has induced several observers to attribute the transport of the larger masses to ice, whether floating down a river or in a lake. It has been suggested that the Potwár may have been converted into a lacustrine basin in post-tertiary times by the elevation of the Salt Range and the ridges west of the Indus. There is but little evidence in favour of this view, but still it is not impossible, for, although the pebble beds underlying the finer silt of the Soán valley appear too coarse for lacustrine[1] deposits the silt may be, in part at least, a later deposit.

The post-tertiary deposits are of course quite unconformable to the Siwalik rocks, which had been greatly disturbed and denuded before the later beds were formed. These later beds themselves, however, are occasionally found dipping at a considerable angle, due, it is said, to original deposition. The pebble beds are found around Ráwalpindi and in the neighbourhood of the Indus; they overlie the Rhotas gorge near Jhelum, occur on some of the Salt Range plateaus, and cap the mountain above Kálabágh on the Indus. They are found at a considerable elevation above the present river beds, some fragments of crystalline rocks in the neighbourhood of the Indus, apparently brought down by the stream, having been observed 2,000 feet above the river.

Erratics.—The large blocks attributed to ice flotation appear to have been derived from the Himalayas. They are abundant along the Indus as far up as Amb, on the left bank of the river, in the gorge of the Sirun and for some miles below Attock, around Jhand about 20 miles farther south, and farther still to the southward near the village of Trap

[1] For additional details concerning these alluvial deposits of the Potwár, see Wynne, Rec. G. S. I., X, p. 122, and Theobald, *ib.* pp. 140, 223.

on the lower course of the Soán. Some of the blocks have been measured nearly 50 feet in girth and others are even larger. In places such blocks have been found 20 miles away from the banks of the Indus.

Indus floods.—The Indus, as is well known, is subject to extraordinary floods, due to a portion of the upper valley being blocked by landslips or, according to some, by glaciers, and to the sudden destruction of the barriers thus formed. Such floods occurred in 1841 and 1858, and have doubtless taken place in past ages.[1] In the flood of 1841, the waters of the Cabul river were checked and forced backwards for 20 miles by the rise of the Indus; and Drew has shewn that the lake in Gilgit formed by the landslip in 1840-41 must have been 35 miles long, and upwards of 300 feet deep. Enormous quantities of detritus must be carried down by the violent floods produced by the bursting of such barriers, and if, as appears probable,[2] the low temperature of the glacial epoch was felt in India, such lakes at an elevation of 5,000 or 6,000 feet above the sea would have been deeply frozen in winter, and large blocks from the river bed and dam might easily have been embedded in the ice; glaciers also in the North-Western Himalayas must have been more extensive than they now are, and the formation of lakes dammed up by glaciers was probably of common occurrence. Shaw[3] has called attention to the occurrence of heaps of stone and gravel of all sizes brought 80 miles down the Shayok, one of the tributaries of the Upper Indus in Ladák, by blocks of ice; and a similar action on a larger scale on the Indus may easily have supplied the erratics of the Upper Punjab. If the Potwár was a lake, the dispersion of the erratic blocks is easily understood; if not, the area over which the masses of rock are found may be due to variation in the course of the Indus, and to the reversed flow of its tributaries in great floods.

Fossil shells.—In one locality near Fatehganj a number of land and fresh-water shells were found[4] in silt, apparently the same as that in which boulders are elsewhere imbedded. The species found, including *Lymnea rufescens, Planorbis exustus, Paludina bengalensis, Bythinia pulchella, Melania tuberculata, Bulimus insularis, Opeas gracilis,* &c., are the same as are now found common in the country, and it appears doubtful if they would have survived any very great diminution of temperature. At the same time it is possible that the beds containing shells may be of later date than those with boulders.

[1] For accounts of these floods, see Cunningham's "Ladak"; Montgomerie, J. A. S B., 1860, p. 128; Shaw, "High Tartary, Yarkand and Kashghar," p. 433, &c., and Appendix, p. 481; and especially Drew, "Jummoo and Kashmir Territories," p. 414. Numerous references to other accounts are given by the last-named writer.

[2] See *ante*, p. 372.

[3] l. c., p. 486.

[4] The Theobald, Rec. G. S. I., X, p. 141.

CHAPTER XXII.

EXTRA-PENINSULAR AREA.

SUB-HIMALAYAS.

Scanty materials — Provisional limits of Himalayas — Map — General features — Three main divisions. THE SUB-HIMALAYAS: provisional conclusions — General features — Early views — General range of deposits — Classification — Petrology — Chiefly of fresh-water origin — Structural conditions — Faults — Flexures — Middle and terminal Sub-Himalayan regions — The Simla region — Order of description. THE SIRMÚR AREA — Unity of the formation — Subáthu, Dagshai, and Kasauli groups — Relation to the older rocks — Section at Subáthu — Eastern limits of the Sirmúr area — Easternmost outlier of the nummulitic group. SIWALIK SERIES: NÁHAN AREA — The Náhan-Siwalik boundary — The Náhan-Sirmúr boundary. THE JUMNA-GANGES AREA — Composition in relation to the great rivers — Identification of beds in the two zones — Suggested connexion of the two zones in this area. THE GAHRWAL-KUMAUN AREA. THE NEPÁL AREA. THE SIKKIM-BHÚTAN AREA. UPPER ASSAM AREA.

Scanty materials.—Information regarding the Himalayas would probably be the first demand made upon an Indian geologist out of India. In the country itself it has been quite the reverse, and so it happens that up to date this information is most scanty. Regular continuous work in the mountains has not yet been attempted by the Survey, or has only just been begun, in the hope that circumstances will permit of its being continued. The whole information upon which to form an outline of this great geological region consists of Captain R. Strachey's account of a portion of Central Tibet, Stoliczka's observations in Western Tibet, and some casual seasons' work, by members of the Survey, in the Lower and Sub-Himalayan ranges, besides isolated observations of more or less doubtful validity by various travellers, whose principal objects of interest were not geological. As presenting some very marked uniformities of structure, the Himalayas as a whole have no doubt a continuous history; but it would be impossible to make it out from such scant data as exist. Each portion of the Himalayan area has more intricate and intimate relation to the history of the whole mountain region than has, for instance, any particular basin of Gondwána rocks to the history of the peninsular area, so that a description of any part of the mountain chain is more dependent upon a knowledge of the

whole. We can only attempt to indicate such main features as have been determined, and to make some conjectures on their possible connexion. This very preliminary condition of our information must be our excuse for a somewhat irregular method of presentation.

Provisional limits of region.—The area to be included under the word "Himalaya" needs to be specified. As originally applied and accepted by excellent authorities, it would mean only the southern face of the Tibetan plateau; whereas of late by geological writers the name has frequently been used as equivalent to extra-peninsular India, with undefined outer limits. Both senses are about equally inconvenient, in opposite ways. Although the name may be retained in its narrowest sense to distinguish the Himalayan range proper from other ranges of the same apparent system, it is also, as that of the principal, or at least the most famous member of the group, commonly understood to indicate the whole of this more or less parallel system of ranges. In these senses we shall here speak of the main line of snowy peaks between the Bráhmapútra and the Indus as the Himalayan range, and of the Himalayan region as extending from the plains of India to the northern scarp of the Tibetan plateau. It is very possible, or even likely, that this geological region or mountain system, may hereafter be very largely extended; but until this is done upon a basis of observation, and to express a meaning more defined and substantiated than any as yet proposed, it would be more confusing than instructive to adopt a wider definition than that given above. For example, the tertiary rocks of the Potwár and of Hazára (between the Jhelum and Indus) are shewn to be continuous with those of the Sub-Himalayas, and to have been affected by the same disturbing causes; yet it is quite necessary to distinguish by name the two regions, as affected by total and abrupt contrast in the direction of disturbance, and of the resulting surface-features. It is certainly most convenient to restrict the word "Himalaya" in this definite intelligible sense, more or less in agreement with the meaning spontaneously attached to it, rather than adopt a new name for the familiar ground, and extend the old one to a meaning without assignable limits.

The geological contrast between peninsular and non-peninsular India is a very striking one: in the former the sedimentary rocks are almost exclusively of fresh-water formation, while the corresponding deposits in adjoining areas are marine; again, the stratified rocks of the peninsula, from the Upper Vindhyan time, have undergone comparatively little compression or alteration, while very late formations in the adjoining area are universally more or less contorted. We can, however, keep in mind the peculiar characters of the peninsular rocks without

extending the term "Himalaya" on the grounds of such general features as marine origin, and disturbance, regardless of special distribution and structure.

Map.—In the map attached to this work, the Himalayan area is correspondingly more incomplete than the peninsula. The blanks are larger, and such indications as are given are less exact, the lines having been more or less conjecturally extended between the observations made on separate routes. Some important observations by Mr. Lydekker in the Kashmir region that are noticed in the text came too late for insertion on the map.

General features.—So far as known, the Himalayas exhibit more regularity of structure than the Alps. There are, no doubt, exceedingly knotty points to be unravelled, but the continuity and similarity of structure which prevail over large areas greatly facilitate description, and give a promise of an ultimate understanding. On a good physical map, the regularity of the boundary between the mountain region and the plains of Northern India is a very marked feature; a steady gentle curve, convex to the west-south-west, without any interruption from spurs or semi-detached masses. Throughout great distances the main features of the mountains, both of structure and configuration, conform to this outer boundary, and thus we may conveniently take up the description in successive zones.

Three main divisions.—Three such zones or natural divisions, of permanent significance, can be indicated. There is on the south a continuous fringing belt of lower ridges, appropriately known as the Sub-Himalayas, and composed of tertiary rocks. Between this marginal zone and the great snowy range there lies, throughout the whole length of the Himalayas to as far west as the Sutlej, a broad area, some fifty miles wide, consisting of irregular ridges of moderate average elevation, from 5,000 to 8,000 feet—some ranging up to 12,000—all largely made up of crystalline metamorphic rocks, in very obscure relation with some unaltered formations, the latter being for the most part of very uncertain age. This great area, so well defined by position, and characterised throughout by extreme complexity of structure, may appropriately be distinguished as the Lower Himalayan region. Although of course the most accessible and the most frequented part of the mountains, it is the least understood. The great snowy range of the Himalayas proper belongs to what may be conveniently distinguished as the Central, or Tibetan, division of the mountains, which is characterised on the large scale by several parallel axes of gneissic rocks and intervening synclinal basins of little-altered, fossiliferous formations. To the west of the Sutlej, and actually on the strike of the

great Himalayan range, the hills next to the tertiary zone have this latter type of structure, and must be classed in the central division. This feature and the corresponding disappearance of the whole Lower Himalayan region at the Sutlej point to a fact which must be constantly kept in mind—that our observations and descriptions refer chiefly to the (partially) terminal portions of the great Himalayan region, most of the middle Himalayas, in Nipal and to the north of it, being unknown to us; so that the divisions and characters adopted in the north-western portion may be inapplicable to the mountain region as a whole. It is, however, to be observed that the fundamental structural characters, from which the history of the mountains is to be made out, may be better exhibited where dying out than in the more elevated middle regions, where a deeper and intensified phase of disturbing conditions would be exhibited.

THE SUB-HIMALAYAS.[1]—**Provisional conclusions.**—The Himalayas being generally supposed to have been upraised in late tertiary times, the study of the tertiary rocks ought to be of special importance, as embracing the most active period in the history of the mountains. Since our sketch of this history cannot be very formal or conclusive, it may assist comprehension to indicate at the outset the provisional views suggested by the observations that have been made, up to the present, in the Sub-Himalayan region. If these points do not specifically agree with current anticipations, they quite bear out the important part taken by the tertiary formations, and the mention of them here will give a meaning and an immediate interest to the descriptive details. Some of these provisional conclusions depend more or less upon single sections, on the report of a single observer, and the verification of them should be an object with every competent explorer, either to confirm or confute. To provoke this desirable service we will give dogmatic prominence to the crucial points. It will be shewn—

(1), that immediately preceding the lower tertiary (nummulitic) period, the area defined as the Lower Himalayas must have been exposed to denudation as part of a land of doubtful configuration;

(2), that the very ancient, slaty rocks of that land upon which, after depression, the marine nummulitic deposits were laid down, had then undergone little or no contortion, where they are now most contorted;

(3), that during the deposition of an immense thickness of the upper tertiary deposits, the Himalayan region was already

[1] For published descriptions of the Geology, see Mem. G. S. I., III, Pt. 2; Rec. G. S. I., IX, p. 49.

defined as an area of denudation in which the great rivers were the same as are now found there;

(4), that the topmost beds (Upper Siwalik) of the Sub-Himalayan tertiary series have undergone extreme disturbance;

(5), that the operation of the forces by which this total of results was accomplished must have been most gradual.

General features.—By abrupt difference of elevation and by contour, the Sub-Himalayan hills are everywhere easily distinguishable from the much higher mountains to the north of them. They very commonly present a steep face to the south, with a more gentle inner slope; and as a general rule they consist of two ranges, separated by a broad flat valley, for which the native name "dún" (doon) has been adopted in India. When the outer of these ranges is wanting, as is the case below Naini Tál and Dárjíling, the whole geographical feature might escape notice, the inner range being confounded with the spurs of the mountains. From a point of view whence all the surface features of this inner range can be seen, it will, however, generally be observed, that the hills are not branching extremities of the spurs from the main range, but true longitudinal flanking ridges, separated from the higher range by a line of gaps and gorges; or at least there will always be noticed a rapid increase of elevation immediately inside the tertiary boundary.

Two places are known, on the Bhútan frontier, where even the inner Sub-Himalayan range is wanting, and the marginal slopes of the plains reach to the base of the Lower Himalayan region; but with these exceptions the fringe of tertiary rocks is, so far as we know, continuous for 1,500 miles, from the Bráhmapútra to the Jhelum, which are the limits of the Himalayan region proper, as here restricted. West of the Sutlej, where the Lower Himalayan area ends, there is an equivalent increase in the width of the Sub-Himalayan zone, made up by a repetition of low ridges and intervening dúns.

Early views on Sub-Himalayas.—Soft, massive sandstone is the prevailing rock of the Sub-Himalayan ranges, but associated in very variable proportions, according to position, with conglomerates and clays. Owing apparently to some suspected connexion with the rock-salt deposits of North-Western India, these sandstones were considered by the early observers to belong to the New Red Sandstone of the European scale of formations. The Vindhyan rocks on the south of the plains were regarded at the same time as Old Red Sandstone; and on the strength of these identifications borings were recommended, if not actually undertaken, along the margin of the plains, to find the carboniferous formation

with its coal.[1] It was the discovery of the famous Siwalik fossils in the outer range of the hills that established the true age of these rocks. Sir Proby Cautley (then Lieutenant Cautley, R.A.) seems to have been the original discoverer of those fossils, prior to 1832[2]; and the great collections were subsequently made by him and Dr. Falconer, and described by the latter, chiefly in the Fauna Antiqua Sivalensis and Palæontological Memoirs. Long after the publication of the tertiary age of the Siwalik rocks, until the examination of the ground by the Survey, the sandstones of the inner range flanking the mountains were still regarded as secondary.

General range of these deposits.—The whole of the Sub-Himalayan zone is formed of these tertiary rocks, with the exception of some inliers of palæozoic limestone in the north-west, where the area is broadest. At this western extremity of the range, on the Jhelum, the whole sedimentary series undergoes an abrupt change of strike, and the tertiary formations, without break of continuity, thus sweep into the Potwár (the upland north of the Salt Range) and across the Indus, passing down into Sind.

In the other direction, the breach of continuity mentioned in the Sub-Himalayan hills on the Bhútan frontier applies also superficially to the rocks, no outcrop of the sandstones having been detected in this position. It is thought that they are only concealed, having been denuded, and then covered up by the diluvial gravels; but it may be that they are altogether wanting, for in this neighbourhood, in Lower Assam, detached hill masses, formed of gneissic rocks of the peninsular type, approach nearer than anywhere else to the Himalayan border. At one spot, indeed, on the east bank of the Raidak (E. long. 89° 47′), Mr. Mallet observed a small boss of this southern gneiss far within the tertiary zone, and only a few hundred yards from its inner boundary.[3] The sandstone intervened between this boss and the very different metamorphic rocks of the mountains; its contact with the gneiss forming the boss was not seen, but we may presume that the relation is one of simple superposition, and that we have here the local extra-

[1] In Notes on the Economic Mineralogy of the Hill Districts of the North-Western Provinces of India, by E. T. Atkinson, B.A., F.R.G.S., Bengal Civil Service, 1877, the following remark occurs:—" But it has never yet been settled whether coal does or does not exist in Kumaun, and until this question has received the attention due to it, the eventual absolute success of the Kumaun mines must remain problematical " (p. 7). There is no further allusion to coal, to indicate upon what facts this hope of its occurrence is based. It may be only a survival of the primitive idea mentioned in the text.

[2] Jour. As. Soc., Bengal, Vol. I, p. 249, 1832.

[3] Mem. G. S. I., XI, 44.

Himalayan base of the tertiary series, the natural junction of such extreme types of rock indicating an equivalent geological break, even the nummulitic beds being absent. These gaps in the tertiary zone do not, however, quite correspond with the nearest approach of the southern gneissic rocks, but lie somewhat to the west; and it may be more to the point to notice that they occur exactly in front of the great gap between the Assam range and the Rájmahál hills through which all the Himalayan drainage passes to the Bay of Bengal. It seems at least probable that the sandstones once were continuous across these gaps, though no remnant of these tertiary beds may now be left beneath the superficial deposits; and at all events it is certain that the Sub-Himalayan hills and rocks occur again in full force and characteristic form through Upper Assam to the Bráhmapútra, where, as on the Jhelum at the western extremity of the range, they bend round across the head of the Assam valley, and there conform to a system of disturbance having a totally different direction from that of the Himalayas proper. All this takes place in a very remote wild country, inhabited by savage tribes, outside the limits of British occupation, so no details of the feature are known beyond the facts given.

Besides the case described in Lower Assam, the only other position within or close to the Sub-Himalayan region where we find an extra-Himalayan base for the Sub-Himalayan series is in the Punjab, on the south side of the Ráwalpindi plateau, or Potwár, where lower or middle Siwalik sandstones rest with quasi-conformity on the nummulitic limestone capping the older fossiliferous series of the Salt Range, as already described in the preceding chapter. Over all the intermediate country, from east to west, the southern limit of the tertiary rocks is altogether a matter of conjecture, for no trace of them is found along the southern edge of the plains, where from beneath the alluvial deposits the most ancient formations of peninsular India crop out; unless, indeed, we are to recognise them, as has been suggested, in the deepest beds of these plains deposits themselves.

Classification.—From the familiar terms "nummulitic" and "Siwalik" used parenthetically in preceding paragraphs, it may be observed that the Sub-Himalayan system contains a pretty full representation of the tertiary series as generally understood, the former deposits being eocene and the latter in part pliocene. The deposits do ample justice to this extended period, their aggregate thickness being computed as between 12,000 and 15,000 feet, or very much more if we take the maximum thickness of different portions in different positions.

Within this region the vertical limits of the series are very well defined, the nummulitic beds at the base are everywhere in abrupt

contact with immensely older rocks, presumably palæozoic; while the topmost Siwalik beds are as often as not vertical at the edge of the plains, and are thus in the sharpest possible stratigraphical contrast with the post-pliocene and recent deposits. For use within this special region the following classification may be adopted for the Sub-Himalayan formations :—

SUB-HIMALAYAN SYSTEM.	Siwalik series	Upper.
		Middle.
		Lower (Náhan).
	Sirmúr series	Upper (Kasauli).
		Middle (Dagshai).
		Lower (Subáthu : nummulitic).

The enunciation of a classified list of formations ought at once to facilitate the progress of description. We should be able to take up each so-called group and point out its exact range. For the bottom and top divisions of our list—the Subáthu and the Upper Siwalik—this might be roughly done; but we should utterly break down in attempting a continuous delineation of the middle zones. This failure is highly suggestive of error; but recognised confusion may be a safer state of progress than imposed order; and the compromise to be suggested is that no single group-list will ever suit the different sections of the Sub-Himalayan zone ; *e. g.*, the break between the Siwalik and Sirmúr divisions, which is the most marked feature in the Simla region (according to the interpretation given), certainly disappears before reaching the Jhelum. Such discrepancies will not surprise any one who can perceive that the Himalayas have been in great part formed synchronously with the deposition of the tertiary series between the Subáthu and Upper Siwalik groups.

Under these difficult circumstances we must crave the reader's indulgence for a less regular form of treatment than has been followed in the preceding chapters, and for the introduction of discussion upon elementary questions not hitherto mentioned, because these are of crucial importance in the mountain-sections. A brief abstract account of each division will be given, and for further details reference must be made to the descriptions of the separate areas.

Petrology.—Sandstone immensely preponderates in the Sub-Himalayan deposits, and is of a very persistent type from end to end of the region and from top to bottom of the series. Its commonest form is undistinguishable from the rock of corresponding age known as Mollasse in the Alps, of a clear pepper and salt grey, sharp and fine in grain, generally soft, and in very massive beds. The whole Middle and Lower Siwaliks are formed of this rock, with occasional thick beds of red clay

and very rare thin, discontinuous bands and nodules of earthy limestone, the sandstone itself being sometimes calcareous, and thus cemented into hard nodular masses. In the Sirmúr group generally, and locally in the Lower Siwaliks, the sandstone is thoroughly indurated and often of a purple tint, while retaining the distinctive aspect. In the Upper Siwaliks conglomerates prevail largely; they are often made up of the coarsest shingle, precisely like that in the beds of the great Himalayan torrents. Brown clays occur often with the conglomerate, and sometimes almost entirely replace it. This clay, even when tilted to the vertical, is undistinguishable in hand specimens from that of the recent plains deposit; and no doubt it was formed in a similar manner, as alluvium. The sandstone, too, of this zone, is exactly like the sand forming the banks of the great rivers, but in a more or less consolidated condition. Thus it was suggestive, and not altogether misleading, to say that the Siwaliks were formed of an upraised portion of the plains of India.

It is only the bottom member of the series that departs widely from the prevailing type of Sub-Himalayan rock. The Subáthu group with nummulites is, of course, marine. Its most distinctive, though not most abundant rock, is a thin-bedded limestone, more or less pure or earthy, associated with clear brown, olive and red, fine crumbling clays; and these latter pass up by interstratification into the strong red clunchy clays, alternating with sandstones, of the middle Sirmúr horizon.

Chiefly of fresh-water origin.—The fresh-water origin of the Siwalik formation seems almost as indisputable as the marine origin of the Subáthu beds; yet, until lately, it has been usual to consider the Siwaliks marine. The notion was probably a relic of the opinion, that a water basin was an essential condition of the extensive accumulation of deposits, and that a sea margin would be required for such a great spread of shingle as that of the Siwalik conglomerates. The same opinion, on the same grounds, has been extended to the plains deposits themselves.

The continued experience that the fossil remains in these tertiary strata are exclusively of land or fresh-water organisms, made this view untenable; and in time it came to be realised that the deposits themselves bear out the same opinion: the mountain torrents are now in many cases engaged in laying down great banks of shingle at the margin of the plains, just like the Siwalik conglomerates; and the thick sandstones and sandy clays of the tertiary series are of just the same type of form and composition as the actual deposits of the great rivers.

Beds of this character alternate with the upper beds of the Subáthu group; so it seems probable that from early tertiary times the sea has been excluded from the Sub-Himalayan region, and that the whole of

the Sub-Himalayan deposits, above the Subáthu group, are fresh-water and fluviatile, and formed on the surface of the land. They are in fact subaërial formations, like the river alluvium and bhábar deposits of the present day.

The striking agreement in character between the Sub-Himalayan rocks and the actual deposits now in progress of formation from Himalayan debris, at once suggests that the mountain border must have been to some extent defined, and the Himalayan area undergoing denudation, from early tertiary times; and it will be seen from the distribution of the Siwalik conglomerates, that during the later tertiary times the configuration of the mountains must have been very similar to what it is now.

Structural conditions.—The validity and meaning of the classification of the Sub-Himalayan tertiary formations depend so much upon the interpretation of certain leading and constant features of the sections, that it is absolutely necessary to preface the descriptions of these features by a brief discussion of certain elementary stratigraphical characters of somewhat exceptional application. Although, of course, not required for the experienced geologist, these explanations will surely be of use to some who may attempt to extend our observations.

The distinction between the original relations of rocks, those resulting from the conditions at the time of formation, and the relations induced by subseqnent disturbance is perfectly clear in thought and in fact. In practice, however, it is often most difficult to discriminate between these relations, and the confusion is at the root of many a disputed position. The reader of the foregoing chapters may already have perceived this in connexion with the question of the nature of the basins of Gondwána rocks (pages 103-106). In the Himalayan sections it is of special difficulty and interest, as bearing upon the question of mountain formation; and some preliminary indications are necessary to a comprehension of the case.

The most remarkable structural features in the Sub-Himalayan zone consist of long lines of abrupt contact of highly contrasting rocks, in which, as a rule, the newer strata dip towards, and so apparently under, the older; and in most cases the beds on both sides of the junction are in normal order, *i. e.*, not inverted. As exposed in the sides of steep valleys, the V-shaped outcrop of the plane of contact, pointing up the valley, towards the older rocks, shews indisputably that these latter are to that extent superposed on the newer. It is quite certain that this could not have been an original relation of these contiguous formations.

Faults.—In every region which has undergone disturbance to any extent there occur what geologists call faults—fissures along which the

rocks on either side have moved up or down, or up on one side and down on the other, resulting in a separation of the once continuous strata. Side movement along the fissure may also occur, but this effect is not here considered. When the fissure is vertical, the displacement is altogether vertical; but when the fissure has a slope, there is a horizontal effect also: if the mass on the upper side move downwards, the ends of the broken beds retreat from each other, leaving a gap between the broken ends of the several strata; but when the opposite movement occurs, the ends of the several beds overlap, so that the newer underlies the older, and a vertical line would pass twice through the same beds on opposite sides of the fault. This latter kind is the least common, and so has come to be called a *reversed* fault. It is clear that horizontal pressure on opposite sides of a sloping plane of fracture tends to produce reversed faults, the movement on the inclined plane being always in the direction of the force producing it.

The feature mentioned as so common on the Himalayan border has *primâ facie* the appearance of a reversed fault. Off-hand judgments are, however, very dangerous in complicated cases: a fault that was originally vertical and normal might easily assume the condition of a reversed fault by a suitable tilt in the whole mass, and it is easy to see that the original relations of rocks might be similarly deformed beyond *primâ facie* recognition. The word "deposit" suggests chiefly a floor of deposition, and other limiting conditions are liable to be lost sight of. We hear, indeed, of geological shores, but chiefly in the sense of shallow bottoms; yet all of us are familiar with cliffs and slopes of every degree. Although due to erosion and always, as cliffs, subject to denudation, these may also form surfaces on and against which deposition may take place, and the resulting rock-feature must always bear more or less resemblance to a fault—discontinuous rocks in steep juxtaposition. It is, moreover, certain that subsequent compression might in this case also produce the resemblance of a reversed fault—the overhanging of older upon newer strata.

These evident chances of deception call for careful examination of the ground in certain cases, and we are not without tests, more or less trustworthy, according to circumstances. A fault, as such, unless it occurs in the bedding or along some other plane of original contact, implies the same series of rocks on each side—that any bed on the downthrow side can be found on the upthrow side, unless removed by denudation; and that any bed on the upthrow side can be found on the downthrow side, unless buried out of sight. Straightness of direction is another special original character of faults, any departure from which

would generally be due to inequalities in the resisting medium when the fracture was made; and in proportion to the magnitude of the fault this interference would probably be ineffectual. Another important criterion between a faulted and an original contact should be found at the very contact itself, and in proportion to the magnitude of the fault. It is certain that slips do occur in the interior of rock masses with scarcely any perceptible effect of crushing or of friction; and it is intelligible how this may take place; but there must be a general tendency to such effects, and often they are most marked. In the case of these reversed faults—the result of lateral compression—the friction must be prodigious, and its effects conspicuous. On the other hand, a steep surface of original contact, by deposition, would have a quite different appearance; although this, too, would be greatly disguised by subsequent compression, such as would convert a normal into a reversed slope of the junction. The leading structural lines so marked in the Sub-Himalayas exhibit mixed characters; in some the evidence is very strongly in favour of faulting; in others there is very decided evidence that the feature is principally aboriginal.[1]

Flexures.—These special lines, the right comprehension of which is so essential to an understanding of the mountains' history, are in some cases traceable into connection with the known direct effects of disturbance, which in this region observe a decided prevailing type, that of normal flexures with the axis-plane inclined towards the mountains.[2] The familiar form of the Sub-Himalyan hills is a direct result of this structural character. The detached Siwalik ranges are mostly formed of a single flexure, the steep southern or outer face corresponding with the high dip of the beds; or else, the strata on this, the southern, side of the axis have been removed by denudation, exposing the scarped edges of the gently sloping strata on the north side. This low dip becomes more or less horizontal, and so forms the area of the typical dún, or longitudinal valley, of the Sub-Himalayan zone.

Middle and terminal Sub-Himalayan regions.—As there are gaps of some 50 to 200 miles between several of the known sections of the

[1] In geological language, this word must mean—from the commencement of the relation, *i. e.*, from the date of formation of the newer rock.

[2] Professor H. D. Rogers' classification (Geology of Pennsylvania, 1858) of the undulations of strata will be found most useful: the *symetrical* flexure, when the inclinations is the same on both sides of the axis; the *normal* flexure (so-called, perhaps, because, the most common in mountain regions), when the dip is greater on one side than on the other; and the *folded* flexure, when the steeper dip has been pushed beyond the vertical, the beds on that side being then inverted. The *axis-plane* is the plane bisecting the angle between the opposite dips. To the above we may add the *monoclinal* flexure, when the beds on one side are horizontal.

Sub-Himalayan zone, the description must be similarly broken, and this method will also best suit the imperfect state of our knowledge even where observations have been continuous. The conditions of the ground lend themselves to this method. One very marked natural division of the Sub-Himalayan rock-features corresponds to the termination of the Lower Himalayan region, about the seventy-seventh parallel of east longitude. East of this line, only the upper tertiary rocks are found, forming a mere fringe to the Lower Himalayas, and consisting often of a single range of low hills immediately flanking the mountains; whereas, to the west, there are always several ranges of Sub-Himalayan hills, and the zone is sometimes 60 miles wide. As the word *central* has been already applied to a division of the mountains in the sense of axial, and as distinguished from lateral, so the word *middle* will be used in a transverse sense, as distinguished from terminal; and thus the contrast here indicated is between the terminal, north-western, portion of the zone and the middle portion. We do not know enough of the far eastern region to say whether there are any corresponding terminal features in that direction.[1]

The Simla region.—The discrepancies that have been mentioned in the classification of the tertiary series on different sections are chiefly connected with this general change of the mountain features, and so the position is one of special importance. For the older rocks, also, the terminal area of the Lower Himalayas will be shewn to be of peculiar interest, so it will be convenient to give this tract a distinguishing name as the Simla region; the name being, of course, derived from the favourite hill station which stands in the middle of the area, on the watershed between the Sutlej and the Jumna. It is here we find the original type area of the Sirmúr series, where a remnant of these lower tertiary formations has been elevated on the margin of the Lower Himalayas. To the east the series disappears altogether, and to the west it passes down into the Sub-Himalayan zone. Corresponding to this elevation of the lower tertiaries, we find here a total separation of them from the upper series; and there is evidence to suggest that the relation between

[1] The words *inner* and *outer* are of frequent use in the description of mountain structure. With some writers they have reference to a point external to the range, to an imaginary centre of dispersion of the disturbing action. In the text these words will be used with reference to central (axial); and as our description chiefly refers to the southern face of the mountain region, this use will not conflict with that other sense of the words, for from that point of view the wave of Himalayan disturbance is supposed to have come from the north.

Longitudinal and *transverse* or *lateral* are also terms of frequent use in descriptions of mountain structure; they refer to directions with, or across, the axis of the range.

the two is of the nature of an unconformity. Here, too, we find evidence for at least a local unconformity in the upper tertiary, or Siwalik series. It seems possible that these two important features may be generally characteristic of the whole middle Himalayan area; while it is certain that to the north-west neither supposed unconformity is maintained, and other structural features are introduced different from any observed in the middle area.

Order of description.—Following these indications, we will first examine these apparently more decisive sections of the Simla region, and then the other areas of the middle Himalayan ground to the east. We will then return and describe the expanded tertiary zone to the north-west, in the Kángra district and the Jamu (Jummoo) hills.

THE SIRMUR AREA.—The typical area of the Sirmúr series is not in the Sub-Himalayan zone, but on the margin of the Lower Himalayas, at their extremity, where the boundary sweeps round to the north up to the base of the Dhauladhár. At this edge of the mountains, convex to the south-west, a remnant of the lower tertiary formations has been preserved, upraised on a basis of the old rocks. The occurrence forms thus an exception to the complete correspondence between the expressions Sub-Himalayan rocks and Sub-Himalayan area; and we have to put up with the anomaly of taking our type section of the lower series of the Sub-Himalayan system from the Lower Himalayan area. Although spoken of as a remnant, the formation here occupies a considerable extent of ground, stretching from the Sutlej for 70 miles to the eastward to within 15 miles of the Jumna, and locally as much as 10 miles wide. All the east end of the area is in the Sirmúr State, so this name has been taken for the formation.

Unity of the formation.—In a more important sense than relative size, the tertiaries of the Sirmúr area are not properly a remnant. Although the latest beds of the series are only found in a few places, they form, with the lower deposits, a series of very complete facies and unity, presenting a gradual passage, by interstratification, from exclusively calcario-earthy marine beds at the base, through clays and sandstones, to an exclusively sandy band at top, in which fossil leaves of plants are locally abundant, suggesting the natural local consummation of a continuous process of deposition. This character is of much importance in discussing the relation to the Siwalik series immediately to the south.

Subathu, Dagshai, and Kasauli groups.—The nummulitic rocks of Subáthu were first described by Major Vicary in 1853[1]; and

[1] Q. J. G. S., IX, 1853, p. 70.

the fossils collected by him were included in the *Description des animaux fossiles du Groupe Nummulitique de l'Inde* (1853) by D'Archiac and Haime, from which work the following list is taken. The authors remark upon the great contrast between these fossils and those from the nummulitic beds of the Salt Range and of Sind; a contrast especially shewn by the total want of corals, bryozoa, echinoderms, and crustaceans in the collections from Subáthu. This discrepancy may perhaps to some extent be accounted for by the prevailing muddy character of the Sub-Himalayan nummulitic deposits as compared with those to the south-west.[1]

GASTEROPODA.

Physa? nummulitica.
e * *Natica glaucinoides.*
e * *N. mutabilis.*
e * *N. Roualti.*
e *N. epiglottina.*
N. cypræformis.
Turbo oldheimi.
Turritella subathooensis.
T. subfasciata.
Cerithium jelumense.
C. stracheyi.
C. hookeri.
Fusus malcolmsoni.
F. macclellandi.
F. obscurus.
Rostellaria rimosa.
Bucrinum, sp. indet.
Voluta multidentata?
e *Terebellum fusiforme.*
e *Ancellaria olivula.*
Conus, 2 sp. indet.

LAMELLIBRANCHIATA.

Panopæa? subelongata.
* *Corbula subexarata.*
Donax crassa.
Cyprina? subathooensis.
C. transversa.
C. semilunaris.
Venus gumberensis.
V. subgumberensis.
V. pseudonitidula.
V. everesti.
V. subeveresti.
V. subcyrenoides.
V. nucleus.
V. semicircularis.
* *Cardita subcomplanata*, var.
C. depressa.
C. mutabilis.
Cardium jacquemonti.
Cypricardia vicaryi.
C. faba.
Arca, sp.
Avicula rutimeyri.

FORAMINIFERA.

e * *Nummulites lucasana, var.*
e * *N. beaumonti.*
e * *N. spira.*

Those marked *e* occur in Europe.
" " * " Sind.

[1] Complete reliance cannot be placed in the recorded distribution of these fossils. In the brief stratigraphical sketch given on pages 175 and 176 of the work, there are several important errors, none of which occur in Major Vicary's own account (*l. c.*) published in the same year; such as the occurrence of large mammalian fossils in beds immediately overlying the nummulitics near Subáthu. Reference was made to Major Vicary on these points: he declared the statements to be erroneous, but could not explain the confusion that appeared in the account of MM. D'Archiac and Haime. (Mem. G. S. I., III, pt. 2, p. 93, note).

In the Sirmúr area, the prevailing rock of the Subáthu group is a fine, pale yellowish-brown, crumbling clay with occasional calcareous bands, or locally some thin beds of purer limestone; dark-greenish shales and sometimes harder sandy beds occur. Even within this small area the thickness of the group varies from 200 to 1,000 feet, as well as can be estimated in these very disturbed sections. At the top of the group, beds of red clay or shale alternate with the typical Subáthu rocks, and more or less rapidly increase to the exclusion of the others, with the introduction of thick beds of hard purplish sandstone. Thus a gradual transition takes place into deposits of strikingly different aspect. The Dagshai ridge is entirely made up of these red clays and hard purplish sandstones of the middle Sirmúr group, which must have a thickness of 800 to 1,000 feet. The sandstone has quite the composition and texture of the Siwalik rock, and when from any local cause it is less indurated and has lost its colour, the two are undistinguishable. The red clays gradually disappear, and on the Kasauli ridge, and elsewhere, we find some 600 to 800 feet of sandstone, with only occasional partings of grey sandy shale, in which the leaves of plants are locally abundant.[1]

The separation of the Kasauli and Dagshai horizons is, of course, less marked and less significant than that of the Subáthu group; and the two would go well together as upper Sirmúrs, as distinguished from the marine nummulitic deposits forming the lower part of the series. But, as suggested already, the further distinction is important for purposes of local comparison. A thickness of 2,000 feet is the least assignable for the series in the Sirmúr area, the whole mountain mass being formed of it, from the water level in the Sursulla, at an elevation of about 2,000 feet, to the summit of Kasauli (6,335), within a horizontal distance of less than two miles; but the disturbance is everywhere excessive.

Relation to the older rocks.—The first thing to notice is, that the Sirmúr rocks in the Simla region do not rest upon the top group of the older formations. All the strata are so tremendously crushed together, and the junctions for the most part so steep, that the true relation is not apparent at once. The newest group of the old, pre-tertiary, rocks is unquestionably the massive limestone, underlaid by a great thickness of flaggy slates, forming the conspicuous hills of

[1] Two of these localities may be indicated: one is on the lower Mall, at Kasauli, at a projecting angle about a quarter of a mile south of the water tunnel; the other is some miles north of Kasauli, on the Budi road, near the stream in the chief re-entering angle on the east side of the main ridge. The leaves were roughly identified as belonging to the natural families of *Sapindaceæ, Ericaceæ, Lauraceæ, Moraceæ, Cycadeaceæ, Coniferæ, Palmaceæ, Cyperaceæ*, and *Gramineæ*.—Mem. G. S. I., III pt. 2, p. 97.

the Bój and the Król on the new road to Simla. The main tertiary outlier lies to the south of the Bój, the junction passing under the flank of this mountain and along two spurs, the opposite sides of which are formed of highly contrasting formations, with converging dips, flaggy slates on the north-east, and thick sandstone and red clays on the south-west. But the deep valley between the Bój and Król is also occupied by the bottom tertiary deposits. In the very great majority of exposed sections of the contact, it would be impossible to assert positively that the existing relative positions are not due to faulting; but crucial sections are to be found; and one such would be enough to prove that the old rocks had been deeply denuded before the tertiary period.

Section at Subathu.—Within the station of Subáthu a typical section of this kind is well exposed. The small flat space north of the parade-ground is on a surface of soft nummulitic clay, the outcrop of steeply compressed beds, on both sides of which the slaty flags protrude. Down the sides of the valley to the north-west the contact can be followed continuously, and it is unmistakably an original junction. The feature is a synclinal fold, and the same bottom layer of the Subáthu group, a peculiar pisolitic ferruginous clay, is in contact with the slates throughout. The horizon of these slates is many hundred feet below the base of the Król limestone; it may even be below the Blaini limestone, which is itself at least 1,000 feet below the Król: these details remain still to be worked out.

Another very important relation is apparent in this section at Subáthu: the same synclinal fold affects the slate series, approximately the same layer being at the contact throughout; from which conditions we may certainly conclude that these slates were still approximately flat at the beginning of the tertiary period. This zone of the mountains is at present one of extreme contortion, most, if not all, of which therefore dates from that late period.

There is other evidence from the Subáthu sections that the prenummulitic surface here was very, and suddenly, uneven. In the little section of local bottom beds near the parade-ground, including altogether, perhaps, 200 feet in thickness, the red clays of the middle Sirmúr, or Dagshai, type are already represented, and this group is found in force ascending the ridge to the south-east; while in the steep flanks of the ridge under Subáthu on the south-west, a much greater thickness is found of the brown and olive clays and thin limestone of the Subáthu group. A still greater thickness of these purely nummulitic beds occurs in the sections along the south margin of the outlier, just inside the main boundary. These facts seem to indicate that there was here

some approach to a margin of the nummulitic sea, the features of which (whether shore or sea bottom) must have consisted of steeply scarped flat masses of horizontal palæozoic strata. A reasonable objection to the introduction of any actual shore here may be found in the total absence of anything like a shore deposit along so steep a coast-line. Even small pebbles are very rare in the Sirmúr series at any point, and the Subáthu group is almost exclusively made up of very fine mud, the calcareous element being quite subordinate in it throughout the Sub-Himalayan region.

Limits of the Sirmur area.—The lower tertiaries of the Sirmúr area do not quite form an outlier, as they are not completely cut off from the Sub-Himalayan zone. A narrow band of Subáthu beds, less than a quarter of a mile wide, crossing the Sutlej at Dihar, connects the Sirmúr area on the north-west with the innermost Sub-Himalayan zone of the Kángra area, where the nummulitic group soon disappears altogether, and is covered by higher beds. To the south-east the Sirmúr rocks have undergone the very opposite effect: owing to a general elevation in that direction, the counterpart of the depression to the north-west, they have been altogether removed by denudation; the bottom beds are the last left, high on the ridge, about 10 miles east by north from Náhan. The south boundary of this area is an exceedingly regular and well-marked feature, an abrupt junction with the younger tertiary formations. The nature of this boundary will form an important subject of discussion in connexion with these latter rocks. The inner boundary of the Sirmúrs in the Simla region is different from any other connected with the Sub-Himalayan rocks: at a few places, as along the south-easterly spur from the Bój mountain, the sandstones and clays of the middle horizon occur abutting steeply against the slates; but for the most part the junction is found in low ground, with the Subáthu clays at the contact, almost always steep and much crushed; and straggling extensions from the main area of the Subáthu group can be followed amongst the old rocks, as, for instance, the band passing north of Subáthu nearly up to Solan, between the Bój and the Król. Several small outliers of bottom Subáthu beds have also been observed, folded up in the slates, as may be seen on the old Simla road, above the Haripur rest-house, close to an outcrop of the Blaini limestone. Over the whole of this area, the massive Król limestone, and a great thickness of the underlying slates, must have been denuded before the deposition of the Subáthu group.

Easternmost outlier of the nummulitic group.—This is the fittest place to mention the one small outlier of the Subáthu group that

has been observed east of the Sirmúr area. A small patch of brown nummulitic clay occurs near the village of Bón, in a depression of the ridge of slates at the east end of the Dehra dún over Rikikés. The outlier is quite isolated, and some miles north of the Lower Himalayan boundary. As this ground, east of the Ganges, has been little examined, it is not unlikely that other such remnants may yet be found there; but any large area of these rocks, west of Nepál, would probably have been brought to notice.

It is thus still an open question, whether the nummulitic formation ever extended continuously along the southern face of the Himalayas, for no vestige of it has been found in the Sub-Himalayan zone of the middle region. The fact that the nearest known rocks of eocene age, at the west end of the Assam range, in the Gáro hills, are made up exclusively of fine clays, precisely like those of Subáthu, need only suggest similarity of origin. In both positions there is a marked absence of purely marine deposits; while in both cases these are introduced extensively away from the middle region, to the north-west beyond the Jhelum, and to the east in the Khási hills. The Assam range is, indeed, outside the Himalayan border, but this border, as we know it, has been in great measure defined in post-nummulitic times. It was, however, approximately fixed, as now, in earliest Siwalik (Náhan) times. Such a change of feature implies a great break between the deposits preceding and succeeding it; and this is a suggested measure of the possible separation of the Sirmúr and Siwalik series in the Simla region and throughout the middle Himalayas.

Siwalik series: Nahan area.—It was in this Náhan area that by far the greater part of the original collections of Siwalik fossils were made, on which account alone this ground must be considered classical. It was here, too, that the study of these formations was first taken up by the Survey; and it so happens that the sections are peculiarly favourable for observation; or at least, features are here exposed that have not as yet been observed elsewhere, and that certainly are generally concealed. This exceptional character might indeed be reasonably taken as an objection to considering this ground as a standard of interpretation for any larger region; however this may be, it is certain that the facts here exposed give us the means of stating, in the clearest manner, one important condition of this question of interpretation, upon which the truth of our history of this mountain region must depend.

The area thus peculiarly circumstanced, in the neighbourhood of Náhan, does not at all correspond in length with the adjoining Sirmúr

area. The latter extends to the Sutlej; whereas, in the Sub-Himalayan zone, the features of the western region begin where the boundary of the Lower Himalayas first trends northwards, near Kálka. Just east of this point the width of the Sub-Himalayan zone is at its lowest. The lower Himalayas themselves are here somewhat protuberant southwards; but there is no exceptional compression of the upper tertiary rocks; the corresponding reduction in width of the fringing tertiary zone is effected by the absence of any trace of a dún. From the west end of the Kaiárda dún, which is the trans-Jumna continuation of the Dehra dún, to the east end of the Pinjor dún, which is the cis-Sutlej continuation of the Una dún, the outer Siwalik hills are confluent, for a length of nearly 30 miles, with those on the north of the Pinjor and Kaiárda dúns; so that the junction of the rocks forming these distinct ranges can be closely followed for that distance. It was from the examination of this junction that a clear separation was proposed between a Siwalik and a Náhan group. It is not yet proven that such a separation is not maintained eastwards, throughout the middle Himalayan region; but it certainly is not distinguishable on the extension to the north-west: and so, a compromise has been adopted—to speak of the inner or Náhan zone, and its representative rocks elsewhere, as Lower Siwaliks.

The Náhan, or Lower Siwalik rocks, forming the inner Sub-Himalayan zone at Náhan, consist mainly of massive grey sandstone, often spoken of as the lignite sandstone, from its frequently containing small nests and strings of fossil wood, which from early times till now have given rise to many sanguine reports of the discovery of coal. In deeper sections red or purple clays occur, associated with thinner, harder, darker sandstones, very like the rock of the Dagshai group. Owing to the contorted and faulted condition of these rocks, and the rugged, covered nature of the ground, accurate estimates of thickness are not easily made: from 2,000 to 5,000 feet may be taken as limits.

The rocks forming the outer tertiary zone, the true Siwalik hills, south of Náhan, consist at top of conglomerates and brown clays associated in very variable proportion, overlying a series of alternating thick, soft grey sandstones, and red and yellow clays. The total thickness may vary from 3,000 to 5,000 feet. In other ground the conglomeratic beds by themselves are at least 5,000 feet thick, with a similar thickness of grey sandstone between them and the Náhan horizon. These beds of the Siwalik hills proper will be distinguished—the conglomerates as Upper, and the sandstones and clays as Middle Siwaliks; even if the separation should not be maintained by fossil evidence, the stratigraphical distinction will be always necessary.

The Nahan-Siwalik boundary.—The junction of the Siwalik and Náhan groups is first described, because it clearly exhibits important characters that will be less confidently appealed to in the case of other boundaries. The topmost beds (conglomerates and clays) of the great series of deposits forming the outer hills, dip steadily towards the base of the higher hills, formed of massive sandstones and subordinate red clays of the Náhan zone. The strike in both rocks is the same, but the dip is generally higher on the inner side. Where the Márkanda crosses the boundary under Náhan, the general effect is well seen, and it closely resembles a continuous ascending section; so much so that the early discoverers of the Siwalik fossils accepted it as such, taking the inner beds to be the newer.

Upon a first recognition of the outer rocks as the newer, the immediate conjecture would be that of a fault; it is the explanation usually applied to junctions such as this. The dips might first suggest a doubt, for they certainly are not such as would, under ordinary conditions, result in connection with faulting. Further examination raises other doubts: the conglomerates of the outer beds are largely made up of stones very like that of the rock forming the contiguous hills, which at once suggests a break other than by faulting. Again, if the feature is due to a fault, it must be one of great throw, but the outline of the boundary, as traced through the hills, exhibits great and sudden irregularities, such as are almost incompatible with a great master-dislocation. One other test remains—that of the actual contact, which it is so rare to find exposed to observation: at a short distance to the east of the Márkanda, and close to where the first symptoms appear of the beginning of the Kaiárda dún, a clear section of the contact was found in a gully at the base of the inner hills, shewing the tilted Siwalik conglomerates abutting against a steep weathered surface of the older sandstones, proving that at this point any faulting whatever is out of the question.[1]

This is quite a crucial section, and until it is disposed of, it must take a ruling part in our consideration of this great boundary question. In any civilised, or even more accessible, country so critical an observation would have been examined by many experts since it was first noticed. That this has not been done is only an extra reason for laying stress upon the point. A conjecture has been offered (by Mr. Theobald) that the newer beds at the contact here are not true Siwaliks, but the same as some beds at the top of the series in the Siwalik hills east of the Jumna, and differing somewhat from the usual type of the

[1] Mem. G. S. I., III., Pt. 2, p. 108.

Siwalik conglomerates. This hint is worthy of notice, but it scarcely affects the question at issue, for the beds indicated, whether we choose to call them Siwalik or not, must be closely related to that series, as being at least apparently conformable to it, and having undergone the same disturbances, and must be totally distinct from any deposits formed subsequently to the elevation of the outer range.[1] Thus we may say that, for this portion of the ground, all the evidence, with one exception, suggests that this boundary is not due to faulting. The exception is the reversed lie of the plane of contact; and it is evident that this condition might be produced by lateral pressure upon an originally normal face of deposition.

Another important point in the discussion of this boundary is, that no satisfactory identification has been made between beds on opposite sides of it in this section at Náhan. If this should be correct, that in the great thickness of rocks outside this boundary none of the inner rocks are represented, the consequences that follow upon either interpretation of the junction are rather startling: if it be a fault, the throw must amount to several thousand feet; and, if it be an original boundary, disturbance of Sub-Himalayan (Siwalik) rocks, with denudation to a prodigious extent, must have taken place within the Sub-Himalayan (Siwalik) period, involving great unconformity here between the upper and lower groups. A compromise may be yet made out; but any possible identification of the beds of the inner zone, in the rock-series of the outer zone, must be low down in this latter series, and so would still leave a large break to be accounted for by the fault or the unconformity, as may be ultimately decided. It should be remembered that in such rapidly forming diluvial deposits as those of the Siwalik formation, very great discrepancies might occur between synchronous beds within short distances, so that great judgment and a full consideration of many circumstances are needed in deciding this question. An explanation of this peculiar unconformity will be suggested in describing its disappearance westward, in the Kángra region.

The most westerly point at which the peculiar Náhan-Siwalik junction has been observed is in the Sursulla, below Kálka, where the

[1] Because of doubts expressed regarding this section, although no one, that I know of, has examined the spot indicated, I have wished much for an opportunity to revisit it. Such an occasion, after a lapse of 18 years, has occurred within the last three months, since the above remarks were written. The position lies on the path to Khairwála from the Rajah's garden on the Márkanda, near the village of Tib. I was disappointed to find that no section of the contact is now exposed, but on this point I never had any doubts of the accuracy of my original observation. I have, however, satisfied myself again that the outer rocks at the contact are the regular Upper Siwalik strata.—H. B. M.

massive horizontal Upper Siwalik conglomerate, forming the surface of the Pinjor dún, takes a strong dip towards its junction with the highly inclined sandstones of the inner zone. Beyond this no contact-section of the Upper Siwaliks has been observed on the north side of the dún for more than 50 miles, to near the Sutlej, where everything is changed, and the conglomerates are nearly vertical, having a slight south-westerly underlie, and are thus in apparent continuous sequence with hard Lower Siwalik rocks forming the ridge of the inner zone. This Sutlej section belongs to the Kángra area.

The continuation to the east is more doubtful: at this end of the exposed contact in the Náhan hills, the tilted conglomerates at the boundary pass on to form the crest of the range on the south side of the Kaiárda dún, and flatten out to form its floor; but no near sections of the junction with the rocks of the Náhan zone are visible.

The Nahan-Sirmur boundary.—Within the Náhan area the junction of the Siwalik and Sirmúr series corresponds with what we shall constantly refer to as the *main boundary;* for we may fairly give this name to the most persistent and striking structural feature of the whole mountain region—the abrupt junction of the slaty or schistose rocks of the mountains with the rocks of the Sub-Himalayan zone. The correct interpretation of this line of junction is a first step towards understanding the history of the mountains. The scarcely disputed admission, that the Sub-Himalayan deposits are in great part made up of Himalayan debris, is at least suggestive that the present boundary may have had something to do with the original one; but the closer inspection of the feature seems always to deter from any further encouragement of this view: the appearance is nearly always that of a reversed fault, the outcrop of the plane of junction in the bottom of the valley being generally inside a line connecting the outcrops of the same plane on the adjacent spurs; and consequently this plane of junction between tertiary and Himalayan beds is inclined towards the mountains. It is only through the Sirmúr rocks in the Simla region that we can bring any direct argument to bear upon this question. Elsewhere there are no terms of comparison between the rocks on opposite sides of this sharp line; whereas here the beds on either side unquestionably belong to the same great tertiary series. We have seen that the upper Sirmúr beds themselves exhibit strongly the type of the Sub-Himalayan deposits, and are also presumably derived from the same source—denudation of the Himalayan area.

The question again turns upon the part taken by faulting. If this main boundary is a *post*-Siwalik fault, we might expect to be able to identify some of the beds on opposite sides. The conditions are

altogether favourable for such a recognition: the highest beds on the upthrow side are sufficiently distinctive, and the beds on the downthrow side are thoroughly turned up and eroded; yet there is no approach to a resemblance; on the contrary, clays become more and more frequent as we get deep in the Lower Siwalik (Náhan) group, and we have seen that the top beds of the Sirmúrs are exclusively sandstone. No trace of the very distinctive nummulitic clays has ever been seen south of the junction, or as fault-rock in the supposed faulted boundary.

These arguments may, of course, be met by magnifying the throw of the supposed fault, so that the Sirmúr rocks should be completely buried out of sight to the south: or a more plausible objection might be raised, that as the outcrops we bring into comparison are for the most part at a considerable distance from the fault, and at a still greater distance from each other, the correspondence cannot be expected; for theoretically, the agreement demanded only holds exactly for the beds originally continuous across the dislocation. It might thus be suggested that the plant-bearing sandstones of Kasauli belong to the same horizon as the Lower Siwalik clays, or the lignite sandstone. Those who have examined the rocks are least disposed to adopt this supposition; and unless one or other of these views is adopted, the argument is binding in favour of this main boundary being an original line of junction, however modified by the subsequent compression to which even the Upper Siwaliks have been subjected.

This conclusion would establish for the middle Himalayan region a very great unconformable break between the upper and lower tertiaries—the Siwalik and the Sirmúr series. It would shew that a great elevation took place, with deep erosion, along the margin of the Lower Himalayan region, in the interval between these formations.

In the case of the Náhan-Siwalik boundary in the Simla region another argument, besides that founded on the contrast of the strata on opposite sides of the junction, was used to shew that the present boundary coincided with the original margin of deposition, and was not a line of fault. This argument was, the very broken direction of the boundary-line. Similar observations apply to the main boundary: the Dehra dún occupies a great bay in the Lower Himalayan area, so that a line joining the termination of the Sirmúr beds in Sirmúr to the small outlier of the same beds east of the Ganges, would touch the Siwalik range south of Dehra; and within this bay the main boundary exhibits several sharp bends, not traceable to cross-faults. Such twists would be scarcely compatible with a great dislocation having several thousand feet of throw, as this boundary must have, if it is to be regarded as a post-Siwalik fault.

THE JUMNA-GANGES AREA.—Although few of the Siwalik fossils were obtained east of the Jumna, it was here the name took its origin, as adopted by Colonel Cautley from *Shib-wála,* the native name for the range separating the Dehra dún from the plains. A more typical Siwalik range could not have been chosen. The axis of the normal anticlinal flexure runs close along the outer edge of the ridge, the beds to the south of the anticlinal having been much denuded, except at the end near the Ganges, where there is a pretty full remnant of the steep southerly dipping beds, gradually becoming vertical in the conglomerates of the little hills west of Hardwár.

Composition in relation to the great rivers.—By comparing this range with its representative in the adjoining region to the west, we find an illustration of the fact already mentioned,—how the Siwalik deposits vary according to their position relatively to the great rivers. The contrast between the rocks of the outer range on opposite sides of the Jumna is so great, that it has been doubted if they can be equivalent; to the west, throughout the Náhan area, clays enter largely into the section, and the conglomerates are made up of the debris of the rocks forming the higher hills immediately to the north, principally the sandstone of the Náhan and the Sirmúr groups; whereas in the range between the Ganges and Jumna, clays are very subordinate, and the conglomerates are composed of the hardest quartzite pebbles, just like the shingle now found in the great mountain torrents. This portion of the range is, in fact, an ancient diluvial fan of the rivers Tons, Jumna, and Ganges. The Jumna, after its confluence with the Tons, now flows very obliquely across the dún, and passes through the outer range far to the west of the point, where it leaves the high mountains, having had to double round the immense accumulation of hard materials it had formerly laid down in front of that gorge. The passes of both the Jumna and Ganges in the Siwalik range are now strongly marked by cross-fractures of the rocks, with contrasting dips on opposite sides; but it is more likely that the rivers helped to determine the position of these fractures, than the reverse; for the rivers have not ceased to flow here since pre-Siwalik times: when the first elevation set in, the rivers had to take to channels of erosion; and when the fracturing forces took effect, these lines of erosion were the positions of least resistance.

Identification of beds in the two zones.—The identification made by Colonel Cautley[1] of certain beds at the south base of the cis-Jumna[2]

[1] Trans. Geol. Soc., London, 2nd Series, Vol. V, p. 271; J. A. S., B, 1834, Vol. III, 528.

[2] The prefixes *cis* and *trans* are used in Upper India with reference to the older British possessions in Eastern India. Cis-Jumna consequently means east of Jumna; trans-Jumna, west.

range with some beds of the inner zone at Náhan is well worth attention. Taking the Náhan beds, by reason of their apparent position, as the highest in that section, he accounted for the non-appearance east of the Jumna of the more fossiliferous strata of the west, by the smaller upheaval in the former position. As already explained, the reverse is the case; and the beds in question, in which fossils were found, at the entrance to the Kálawála pass (cis-Jumna), the same as in the Náhan beds, are probably older than any in the outer range trans-Jumna. A closer search might detect the suspected unconformity between these beds at the south end of Kálawála pass and the overlying Siwalik sandstones. The greater abundance of fossils in the range trans-Jumna than cis-Jumna may easily be due to the contrasting nature of the deposits.

Suggested connection of the two zones in this area.—The complete confirmation of the identification mentioned in the last paragraph, need not disturb the view given of the equivalence of the outer ranges on opposite sides of the Jumna; but this equivalence has been questioned. Throughout the dún east of Dehra there is no representative of the Náhan range, any remnant of these rocks being covered by a great bank of detritus; but in the western dún this inner ridge of the Sub-Himalayas is well defined, and in the Nún, under Mansúri (Mussooree), there is a peculiarly puzzling section. The stream, as usual, has cut a steep narrow gorge through the flanking ridge of the massive lignite sandstone, here nearly vertical, but with a slight inward underlie; and just below the gorge there is in the low banks a nearly continuous section of seemingly conformable beds, in which the sandstone becomes pebbly, and gradually alternates with strong beds of conglomerate, the northerly underlie being steady throughout. According to the universal order in all normal sections, conglomerates always increase in the upper beds, so this section in the Nún must be an inverted series, and it most resembles that in the range south of the dún.

If this link should be confirmed, we should have to recast the view sketched above regarding the relations of the cis- and trans-Jumna Siwaliks; for there is every reason to suppose that the massive sandstone of the Nún is the same as that of Náhan, with which it may be said to be continuous. There would then be much plausibility in the view once advocated by Mr. Theobald (in an unpublished report), that the original Siwalik hills are chiefly composed of Náhan rocks, and that the more fossiliferous and newer trans-Jumna Siwaliks are not represented to the east of the river, having been denuded away, or else never upheaved.

The alternative interpretations, to reconcile the Nún section with the current opinion of the equivalence of the outer Siwaliks on both

sides of the Jumna, would be—to suppose that the Nún conglomerates are true top beds of the Náhan group, and quite different from those of the outer range; or else, to suppose a break, by a concealed fault, in the apparently regular sequence between them and the lignite sandstone. The question must be worked out on the ground: though it is needful to point it out, it would be out of place to discuss it further in these pages.[1]

THE GAHRWAL AND KUMAUN AREA.—These hill districts correspond with the Rohilkand division of the plains, between the Ganges and the Nepál frontier. This ground has scarcely been looked at. Within ten miles east of the Ganges the Siwalik rocks proper are well represented, and a narrow belt of Náhan beds separates them from the slaty rocks of the Lower Himalayan mountains. Further east, the outer range, and the rocks forming it, seem to be generally absent; and the inner hills, formed of the massive sandstones supposed to belong to the lower Siwalik or Náhan group, become very prominent. The steady north-easterly dip prevails, wherever observations have been made. In General Strachey's paper on this part of the Himalayas[2] a very important observation is recorded, that the trap-rock of the Lower Himalayas enters the sandstone of the Sub-Himalayan zone. The position is in the Gola river south of Bhimtál. No fact of the kind has been noticed elsewhere.

Operations have been undertaken to smelt iron on a large scale from an ore concentrated in the red clays at the base of these hills under Naini Tal. Similar ferriferous clay is known to occur near Náhan, and again in the same rocks far to the east in Sikkim.

NEPÁL AREA[3].—For a length of 500 miles the kingdom of Nepál completely arrests all study of Himalayan geology, with the exception of the single track to Kathmándu (Katmandoo), and a small area around the valley. On this track very complete representatives are found of the two Sub-Himalayan ranges and their intervening dún or *mári*, as the valley is called here. The Chúriagháti range is structurally a *facsimile* of the original Siwaliks. At the outer base, at Bichiako, there are some earthy rusty beds, all greatly crushed. The dip soon settles down to 30° to north-north-west, maintaining the same angle steadily to the top of the pass.

[1] Salt-pans were once set up on a small scale in the gorge of the Nún: it is not known whether this enterprise was started on the strength of the name *nún* (salt), or on account of the efflorescence that is often locally abundant on exposed surfaces of the lignite sandstone, or on the trust of some tradition of the occurrence of rock-salt.

[2] Q. J. G. S., L, 1851, Vol. VII, p. 296.

[3] Rec. G. S. I., 1875, VIII, p. 93.

This is the typical structure of these detached Sub-Himalayan ranges, the flat inner half of a normal anticlinal flexure. The range is about four miles wide, which would give an aggregate thickness of about 10,000 feet of rock. The pass, as is universal in these ranges, follows the broad bed of a torrent to near the summit, where the road turns up a steep gully, partly artificial.

The lower half of the section is sand, and the upper half conglomerate. In the Siwaliks of the North-West the passage between these two rocks is gradual and alternating; in the Chúriagháti section it was noticed that the change is rapid and complete, from an almost unbroken mass of fine grey sand to an equally uniform mass of pale yellowish-brown conglomerate. This may not be a point of any importance; but special notice was made of the exceedingly fresh aspect of these deposits as compared with the rocks of the original Siwalik range,—a point that may have some meaning in connexion with Mr. Theobald's suggestion, already mentioned, that the latter rocks may belong to the Náhan horizon. In this respect the rocks of the Chúriagháti range more resemble those of the outermost hills of the trans-Jumna region.

This same newness of aspect may be noticed in comparing the Chúriagháti rocks with those of the inner Sub-Himalayan range on the north side of the dún at Etaunda (the rest-house on the road to Kathmándu), in order to represent the apparent impossibility of the two ranges being a repetition of the same rock-series; and hence the presumption that their junction is not a fault. In the Rápti, immediately under Etounda, there are outcrops of the rusty sandy clays and greenish-grey hard sandstone at the base of the section to the north. They dip at 60° to north by east. Wherever observed along the road, this dip (with slight variation in amount) was found constant, and there is but little change in the character of the rock. Clays occur, but very subordinately; the sandstone becomes somewhat softer in the higher beds, and there are here several layers of thin conglomerates. It is clearly a normal ascending section, and in no particular is there any near resemblance to the series of the outer range. The section here is about two miles wide, which would give a thickness of about 10,000 feet, there being nothing to suggest repetition by faulting or flexure. As usual, the contact with the rocks of the mountain is concealed.

Regarding the interpretation of this section: we might explain the actual difference of composition by the presumable difference in successive zones of one great belt of torrential deposits, and the actual differences of

texture by the presumable greater induration of the inner band, and thus make out that the two rock-series were originally continuous and equivalent, and that their present relation must be due to a great fault. The impression made on the observer was decidedly against that equivalence; and hence, that the present relative position is, like that in the Náhan section, to a great extent aboriginal.

Sikkim and Bhútán areas.[1]—Throughout the Sikkim and Bhútán Duárs there is no representative of the Siwalik hills (the outer zone of the Sub-Himalayas); and in two places the Sub-Himalayan rocks are altogether absent, or concealed.[2] One of these gaps, about 10 miles wide, is just south of Dáling Fort, and corresponds to a marked promontory of the older rocks of the mountains. The other gap is much longer, from the Jaldoka to beyond the Tursa, a distance of 40 miles, and throughout this area also the base of the mountains is prominent and irregular. It seems probable (see p. 522) that the absence of the tertiary sandstones in this ground is due to their partial removal, and the complete concealment of the denuded outcrops by the great gravel deposits that are here accumulated at the foot of the hills. There is nothing in the old rocks to suggest their former greater extension in this position: the Damúda rocks also are absent, but here, as elsewhere, the same belt of slaty formations separates the gneissic rocks from the plains.

In close proximity to these gaps, the hills and rocks of the inner Sub-Himalayan zone are in full force, shewing no tendency to thin out towards those blank areas. In the Máhánadi the thickness is estimated by Mr. Mallet as 11,000 feet, and the characters are the same as noticed elsewhere; soft massive grey sandstone being the prevailing rock, with occasional clunchy clays, especially towards the base, where these are sometimes highly ferruginous. Nests of poor lignite, and even small broken seams, occur in the sandstones. The upper beds are often conglomeratic, sometimes coarsely so. In all there is a prevailing dip towards the mountains, so the highest beds occur next the main boundary, but no actual contact-section of this feature has been described. It is clear, however, that whatever explanation of it can be made out elsewhere will apply here also.

Upper Assam area.—To the east of Bhútán the Himalayas north of the Assam valley are occupied by various tribes of savages, and the only observations worth mentioning of that ground are those made by

[1] Mallet: Mem. G. S. I., 1874, XI, p. 45.
[2] First noticed by Colonel Godwin-Austen, J. A. S. B., XXXVII, p. 117.

Colonel Godwin-Austen[1] in the Daphla hills of the Dikráng basin, adjoining the Darrang and Lakhimpur districts of Upper Assam. Here again there are two well-marked ranges of Sub-Himalayan hills, with an intervening dún. Each range is formed of a normal anticlinal flexure, directed from the mountains,[2] just as at the base of the North-Western Himalayas; and the inner range is, at least in great part, formed of older beds than the outer one. Here, too, nests of lignite are of frequent occurrence in the sandstone.

The same lignite sandstones have been observed more to the east, north of Dibrugarh, with the usual high northerly dip.[3]

[1] J. A. S. B, 1875, XLIV, p. 35.

[2] *i. e.*, having the axis-plane sloping towards the mountains (see note, p. 528).

[3] Mem. G. S. I., IV, p. 393.

CHAPTER XXIII.

EXTRA-PENINSULAR AREA.

SUB-HIMALAYAS—(*continued.*)

TERMINAL SUB-HIMALAYAS: THE KÁNGRA AREA — General structure — The Ghambar-Basauli fault — The Kosari and Badsar-Nurpúr faults — Extinction of the Náhan-Siwalik boundary — The Sutlej at Bubhór — Local extinction of the Náhan-Sirmúr boundary — Difficulties of classification in the Kángra area — Bubhór and Beláspur sections compared — Doubtful beds in the Sirmúr zone — Want of fossils — The base of the Dhauladhár — North-western termination of the Kángra area — The Mandi rock-salt. THE JAMU AREA — Boundaries — Special feature — Sirmúr zone at the Rávi — Western expansion of the Sirmúr zone — Inliers — Characters of the Subáthu group — Tertiary-palæozoic relation — Comparison with sections of the Simla region — Doubtful newer rocks of the Sirmúr zone — Other general features of the Sirmúr zone — Sirmúr-Siwalik boundary — The Basauli-Naushera fault — Riássi conglomerates — The outer Siwalik zone. SUMMARY.

TERMINAL SUB-HIMALAYAS: **Kangra area.**—In the last chapter the Sub-Himalayan rocks were traced from the typical Simla area to their eastern extension in Assam; we have now to return to the North-West Himalayas and examine the sections to the west of the Simla region.[1] The great and rapid expansion of the tertiary zone to the north-west corresponds with the extinction of the Lower Himalayan region. From about half-way between Náhan and Kálka the "main boundary" bends steadily inwards, and continues this northerly course for nearly 80 miles, to the base of the Dhauladhár ridge, which is directly on the prolongation of the main snowy range of the middle Himalayas. The Sub-Himalayan ranges are for the most part unaffected by this bend of the main boundary; and thus the ground on the prolongation of the Lower Himalayas is occupied by tertiary rocks, 60 miles wide inside Hoshiárpur. The greater part of this area, up to the Rávi, is in the Kángra district; but this geological field, designated as the Kángra area, must be understood to begin east of the Sutlej,

[1] It would be impossible to give any idea of the structure of this ground without mentioning features and localities that are not indicated on the small map accompanying this work: it will therefore be difficult to follow these descriptions without reference to a larger map (see note, p. 560).

about the east end of the Pinjor (or Kálka) dún. The Sutlej and the Biás flow westwards, across the terminal boundary of the Lower Himalayas, and traverse the dúns and ridges of the Kángra area in very zig-zag courses.

General structure.—The outer Siwalik range of the Kángra area is continuous with that of the Náhan area; so it will appear that the great spread of tertiary rocks to the north-west takes place for the most part on the prolongation of the Náhan, or inner Sub-Himalayan, zone of the middle Himalayan region. Both boundaries of this zone, as lines of contact of dissimilar rocks, change in character and disappear; and in the middle of the expanded zone new features supervene, flexures and great faults, unlike anything as yet observed in the ground to the east.

A more peculiar feature of the terminal Sub-Himalayas is the introduction of an inner zone of oldest tertiaries, not represented at all in the middle Himalayas, but on the prolongation of, and actually continuous with, the Sirmúr series, on the margin of the Lower Himalayas in the Simla region. The Sutlej may be given as the point where the Sirmúr rocks take their place as belonging to the Sub-Himalayas; and a great change rapidly supervenes in the aspect of all the rock-features. In all the zones the introduction of apparently higher beds to the north-west is the rule.

It has been already observed that our representation of the Sub-Himalayan series depends mainly upon the interpretation put upon certain leading structural features peculiar to such mountain regions, and which are markedly homologous in all the formations; our attention must therefore be principally turned upon those features; and as their characters are perhaps best exhibited in their less extreme form, among the newer rocks, the rule observed in this work, to proceed from the oldest to the newest, cannot be followed.

The Ghambar-Basauli fault.—At the east end of the Pinjor dún, in the section of the Mangrad, south-south-east of Kálka, the Náhan zone is scarcely a quarter of a mile wide; the strata are vertical, and all of the lower type noticed in the Náhan section, hard purplish sandstones and red clays. North-north-west of Kálka, rocks of this stamp, in a very contorted condition, form a confused congeries of hills in the Mailog and Nálagarh States. About Khadi, close to the main boundary, on the Subáthu and Budi road, higher beds occur, paler, softer, coarser sandstones; and there is the beginning of a distinct feature, a faulted synclinal flexure, diverging steadily from the main boundary to the north-west. In this direction the character of the

dislocation becomes rapidly developed, and in the valley of the Ghambar it is perfectly defined as a great fault, thick conglomeratic sandstones dipping steeply to the north-east towards, or under, deep red clays and hard sandstones. It follows a remarkably straight course across the Sutlej, through the Kángra district, to Basauli on the Rávi, and thence to Riássi on the Chináb, where it again joins the outer Sirmúr boundary, after a course of nearly 200 miles. It is well seen at many places, as in the Banganga river near the main road to Kángra; about Kotleh on the Bhágsu-Nurpúr road, and at Basauli on the Rávi. The actual contact is always disguised, but there can scarcely be a doubt that it is a great fault, of the reversed order that is most usual in these mountain sections: the strata on opposite sides are nearly parallel to each other, the upthrow is persistently on the inner side, and so the newer rocks in normal order (*i. e.*, not inverted) actually underlie the older; as if in a double folded flexure the upper side of the anticlinal had subsided on, or been pushed over, the lower side of the synclinal limb, the contortion itself having been removed by denudation.

At Juálamuki on this line of fissure there is a temple built in which flames issue continuously from the ground round the base of the idol. At Lunsu, under Dalhousie, there is a mineral spring on this same line of dislocation.

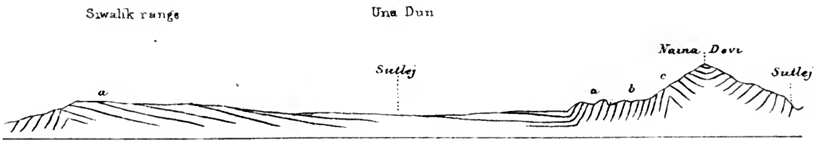
The Kosari and Badsar-Nurpur faults. — South of the Ghambar, the complex range of the Nálagarh hills continues up to the Sutlej, where two lines of dislocation take their rise and result in steady, well-defined ridges to the north-west. The southernmost of these lines is known as the Kosari fault, from a village on the bank of the Sutlej at the north end of the Bubhór gorge; it is comparatively a minor feature, running down the centre of the compacted group of ridges into which the Parwain range is divided on the south-east. The Badsar fault, called after a village 20 miles from the Sutlej, at the north base of this same range of hills, is a principal structural feature of the trans-Sutlej Sub-Himalayas, being continuous for 300 miles up to and beyond the Jhelum. It clearly originates in an anticlinal flexure, and is again recognisable as such at several points of its course, as at Nurpúr; sometimes the dislocation is small, but, as a rule, there is much faulting; and towards the Sutlej the downthrow is on the north side. The Nadaun dún lies in a trough between the Badsar and Ghambar faults.

These great lines of dislocation determine the chief features of the upper tertiary zone of the North-West; and we have seen that they are quite unconnected with any feature of the tertiary zone of the middle

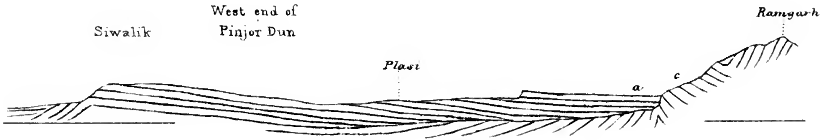
Himalayas. With the introduction of these new features, characteristic of the north-western region, the two chief structural features of the Sub-Himalayas in the middle region—the Náhan-Siwalik and Náhan-Sirmúr boundaries—become extinct. These boundaries have already been interpreted as primarily unconformities, marking decided divisions in the tertiary series; and thus we already find established, in the middle of the Kángra area, the difficulty to be confronted throughout the tertiary series of the North-West, the absence of any well-marked stratigraphical horizons.

Extinction of the Nahan-Siwalik boundary.—This boundary, as described to the east (p. 537), with top Siwaliks abutting at various angles against crushed Náhan beds along a very zig-zag line of junction, continues all along the Pinjor dún to beyond Nálagarh, 16 miles north-east of Rupár (Roopur), where lofty terraces of brown Siwalik clays lie flatly close up to the ridge of crushed red Náhan rocks. Seen in such juxtaposition as this, the possibility of a conformable transition between the two would appear out of the question; yet such is apparently the case within 15 miles to the north-west. North of Anandpur, low flanking hills, formed of these same upper Siwalik strata, turned up and vertical, rise in front of the ridge of the red rocks. A section is recorded just north of Nanowal (close to Anandpur), where the very strata forming the dún turn up, within a space of 100 yards, from being horizontal to a dip of 80° to south-west; in the section to the north they pass down into the grey rocks of the middle Siwaliks. On this section, under Naina Devi peak, there is still an abrupt, probably faulted, contact of the grey and the red rocks, all being parallel and vertical; but on the continuation of the same strike, where the Sutlej cuts a deep gorge through the ridge, and the section is fully exposed, it is impossible to draw a line between the two types of rock. Within 10 miles farther to the north-west any semblance of a continuation of the original Náhan-Siwalik boundary is lost; the dip flattens, and the Naina Devi ridge, as defined by a core of the harder rocks, disappears, all the strata rolling over round the end of the ridge.

In the annexed figures an attempt is made to illustrate the interpretation put upon the observed facts. Throughout the western region superficial features of the same character as those on section B, between *a* and *c*, are interpreted as great faults; where beds several thousand feet apart in geological position are found in abrupt contact. The reasons for taking such a totally different view of like features in the eastern sections are: 1st, that the horizontal features (the outlines in plan) of the junction are strikingly different; in the west they observe a



A. WESTERN SECTION



B. EASTERN SECTION

Diagramatic Sections (16 Miles apart) showing relations of Siwalik Series east and west of the Sutlej.

a, Upper Siwalik. b, Middle Siwalik. c, Lower Siwalik (Nahan).

Scale Horizontal 1 Inch = 4 Miles; Vertical 1 Inch = 8000 feet.

straight or very flatly curved course throughout great distances, while in the Simla region the Náhan-Siwalik boundary is extremely and sharply irregular in direction; and 2ndly, one section of the actual contact was observed here, giving independent and absolute evidence against faulting in that position. The reading to be taken from these sections is, that the disturbance began earlier, or progressed much more rapidly, in the east, and took effect as elevation over a broader area, entailing a greater denudation of the lower group along the axis and in its neighbourhood; while in the west the disturbance took effect as greater compression of the flexure and a more contracted elevation. In both cases deposition progressed continuously and conformably in the adjoining ground, and the latest accumulations gradually overlapped the denuded eastern area, producing extreme local unconformity along a narrow belt of outcrop, while the same beds in the western section became involved in the continued compression of the flexure at that point.

The Sutlej at Bubhor.—The explanation just given of the change in the Náhan-Siwalik boundary, and its disappearance westwards, may seem somewhat fanciful, involving extreme unconformity and continuous sequence of strata within a very narrow space; but we find in this very ground, in one of the sections compared (that of the Sutlej through the Naina Devi ridge at Bubhór), most remarkable independent proof of that slow, creeping action of the disturbing forces which is all that is required for the result claimed. The same facts will furnish a very striking instance of the statement already made regarding the composition of the Siwalik rocks in relation to the actual rivers, and the pre-Siwalik age of the segreat drainage channels.

The Upper Siwaliks at Bubhór are entirely formed of coarse conglomerates, just like the shingle in the river bed; and the grey middle Siwaliks are pebbly throughout, all being vertical as in the figured section A; while within 5 to 10 miles on either side of the river, common brown clays constitute the bulk of the upper group, conglomerates being quite subordinate. The same distribution of deposits is observable in the outer Siwalik range, the case being analogous to that already described for the Jumna and the Siwaliks of Dehra (p. 541). Instead of making a passage through the strong conglomerates opposite the gorge at Bubhór, the river has crept round by Rupár, where the strata forming the range are altogether clays. It seems impossible to avoid the inference, that the Siwalik conglomerates of Bubhór were formed when already the Sutlej had been fixed in its present position by a gorge in the axis of the Naina Devi ridge, formed of the tilted Náhan, or Lower Siwalik strata, which are still an apparent conformity with the said conglomerates.

This is not a conjectural inference, as in the case of the boundary, but one that scarcely admits of an alternative; as it would be more wonderful still to suppose that the river kept its position throughout all that disturbance, without any initial obligatory point in the neighbourhood above Bubhór. Besides, the deposits in question are such as are only found near the mouth of a torrential gorge. After that gorge was first marked out in the rising flexure of the Náhan strata, the river must have scattered its boulders and gravel over a wide space on either side; while at the same time the flexure was steadily encroaching, and so slowly as not to break the continuous parallelism of the series, the lowest bed of which may have been vertical before the highest was deposited. The required result can easily be imagined with the aid of the figured section, page 550: a greater concentration of the flexure would change the local overlap-unconformity in figure B into the apparent conformity of figure A.[1]

This conclusion as to the age of the Naina Devi ridge, the second (from the outside) of the Siwalik ranges on the Sutlej, must bear some weight in the discussion of the equivalence or otherwise of certain analogous or homologous deposits, external or internal to that range. But it must not be forgotten in this connexion, that this case of the Náhan-Siwalik boundary has suggested a longitudinal as well as a transverse progression in the disturbing action, so that analogous deposits on the same continuous zone need not be, or cannot be, strictly equivalent in time, any more than exactly similar deposits in the several successive homologous zones.

Extinction of the Nahan-Sirmur boundary.—The Náhan-Sirmúr boundary of the Simla region and of the Náhan area is one and the same as the main boundary of the middle Himalayas (p. 528)—the junction of the tertiary Sub-Himalayan formations with the old rocks of the higher mountains. The presence of the Sirmúr outlier on the Lower Himalayas of the Simla region does not alter this condition, which continues in force for some distance into the Kángra area. For a length of 20 miles near the Sutlej a ridge of old limestone, along this junction, separates the Sirmúr outlier from the Sub-Himalayan zone. Near Beláspur this ridge trends to east of north, and Sirmúr rocks take its place at the boundary, while the ridge crosses the Sutlej at Dihar; but just beyond the river it dies out in the midst of nummulitic clays.

The presence of the Sirmúr rocks, composed in their upper measures of distinctly Sub-Himalayan deposits, enabled us to discuss the nature of

[1] The necessary distortion of these sections, to make the lines visible, greatly reduces the verisimilitude of the features.

this main boundary, with the result that it is probably of pre-Náhan origin. Evidence to the same effect is found on the continuation of the boundary up to the Sutlej. Although the lower Siwalik (Náhan) rocks of the Mailog and Nálagarh hills are greatly disturbed and deeply eroded, no trace of the distinctive rocks of the contiguous Sirmúrs has been detected; on the contrary, we find here strong additional evidence of the asserted unconformity in the eastern region. Although clearly on the prolongation of the Náhan zone, the rocks of the Mailog hills do not closely resemble the corresponding rocks of the Náhan area; the massive lignite sandstone is not developed, red clays and hard sandstones prevail, like those at the base of the section at Náhan, and where higher beds occur, they are different from any seen to the east. They come in gradually along the main boundary, and are in force in the valley of the Gamrola and at the Sutlej. They consist principally of thick conglomeratic sandstones, and the debris is largely composed of Sirmúr rocks, including the Subáthu nummulitics. Thus it is clear that the older tertiaries were indurated and undergoing denudation at the time when these Gamrola conglomerates were deposited. Whether these latter are really of lower Siwalik age is a point upon which some remarks will be presently made.

The boundary continues in a very direct line nearly due north, for some 20 miles beyond the Sutlej, into the basin of the Biás. The contrasting characters are well displayed nearly to the end, soft grey conglomeratic sandstones dipping flatly eastwards, close up to dark red clays and hard purple sandstones of the Sirmúr zone, with a high dip in the same direction. At one spot, near Dubrog, a contact is obscurely seen: coarse conglomerates, here containing well-rounded boulders of quartzite and gneiss, 2 feet in diameter, shivered to splinters *in situ* by the crushing they had undergone, are found jumbled together with the red rocks, and not confined to a definite vertical band; the conglomerate occurs *in situ* at 100 yards east of an outcrop of the red rocks, indicating a steep overlap or a broken fault. Higher beds come in rapidly to the north, on the upthrow side, indicating the dying out of the dislocation; and at last the strata are continuous across the prolongation of "the main boundary" of the eastern region, so that here one can pass without any break from the Náhan zone into the Sirmúr zone; and the fresh-looking conglomeratic top beds of the former appear to be in regular sequence with the Sirmúr series.

The invasion of the Sirmúr zone by the rocks of the Náhan zone is not, however, complete. Another independent dislocation some 4 miles to the east takes the place of the extinct boundary, overlapping its end

and running to the north-west in a broad curve, parallel to the shore of the great bay of the tertiary formations, near the head of which the Biás issues from the mountains. After a run of about 40 miles this substitute dislocation ceases, and is again replaced near Barwárna (5 miles south of Pálampur) by an exterior line of boundary, on about the prolongation of the old main boundary. The recurrence of a similar feature on the same strike looks as if an early line of upheaval had been worn down and overlapped by later deposits; but this suggestion of the underground direct continuity of these equivalent boundaries on opposite sides of the Biás may be only imaginary. It is perhaps more likely that the peculiarly symmetrical arrangement of these structural lines near the Biás should be a necessary adaptation of the planes of fracture in the tertiary basin to the form of the compressing surface. From Barwárna the restored Náhan-Sirmúr boundary becomes again a very permanent feature, traceable continuously through the Jamu hills to near the Jhelum. To the north-west of the Sutlej, however, where the Sirmúr series takes its place in the Sub-Himalayan zone, this line of junction can no longer be styled the main boundary; this title must be reserved for the contact of the tertiary rocks with the old rocks of the mountains (p. 539); and although the hills of the Sirmúr zone have a very markedly greater elevation than those of the newer tertiary area, there is always a greater orographical contrast accompanying the change from the tertiaries to the old rocks.

Difficulties of classification in the Kangra area.—We have now lost sight of the features which enabled us to trace exact divisions in the tertiary series in the Náhan area. Even the great boundary which in the north-west, as in the Simla region, separates an inner zone of lower tertiary rocks, is partially obliterated in the neighbourhood of the Biás, where one can pass from conglomerates of Siwalik type down to nummulitic beds without apparent stratigraphical break. Unconnected with those boundaries we found in the Kángra area great persistent lines of separation, having more distinctly the stamp of dislocations. If one could frankly accept these lines as faults, pure and simple, in a completed series of deposits, such as can be represented in a diagram, the correlation of the strata would be an easy matter; for in each area so cut off, we find a sequence of deposits having a very decided general likeness, marked by harder, redder beds at the base, and by conglomeratic beds at top. Two considerations are, however, always present to sap one's confidence in such ready identifications. There is the condition of the almost incredibly slow creeping manner in which the features of disturbance were produced; so that, although we must accept these lines of dislocation as primarily fractures, there can be no certainty that the fault is of later

date than strata found disturbed in its immediate neighbourhood—that the conglomerates on the upthrow side of the Ghambar fault are not older than similar beds in unbroken sequence with fractured strata on the downthrow side. And from the other point of view it is to be remembered, that from late nummulitic times the conditions of deposition of these tertiary rocks have been very much alike—rain and river accumulations, on the margin, and from the debris, of the Himalayan region : so that a conglomerate of an early diluvial zone might be undistinguishable from a very much newer rock in an outer zone of the same geological field, and thus utterly stultify the *primâ facie* conclusion of their geological equivalence.

A couple of examples will illustrate the difficulty of any detailed delineation of equivalent stratigraphical horizons in the Sub-Himalayas of the North-West.[1]

Bubhor and Belaspur sections compared.—In the section on the Sutlej above Bubhór, fossils are found rather frequently in the middle Siwaliks, at a defined horizon, below some 4,000 to 5,000 feet of conglomerates. Proceeding up the river, we find, below and above Beláspur, between the Ghambar fault and the main boundary, a succession of strata that would in many respects answer to those of the Bubhór section : the hard red beds at the base are exactly similar; the middle grey beds are only more massive in the Bubhór section; but the conglomerates are quite different. The massive beds of Bubhór contain exclusively the rounded hard shingle only found in and near the great Himalayan torrents, whereas the conglomerates along the Náhan-Sirmúr junction in the Gamrola valley near Beláspur, even where cut by the Sutlej, are made up of local debris, principally of the hard sandstones of the Sirmúrs, but containing also pieces of the softer fossiliferous nummulitic beds of the Subáthu group. The lithological contrast is fully exhibited on the spot, for all about Beláspur, up to 200 feet over the river, there is a thick deposit of old Sutlej shingle, just like the Siwalik conglomerates of Bubhór, but probably of post-tertiary age, corresponding to

[1] In the description of this area published in 1864 (Mem. G. S. I., Vol. III) an arbitrary compromise had to be made on this score, as time did not admit of a further study of the ground. The Náhan zone was distinctively coloured up to the Sutlej ; but in the country beyond, much the larger area being occupied by the higher beds, of presumably Siwalik age, the whole of that area was coloured as Siwalik, rather than attempt to put in from memory the outcrops of the lower horizons, presumably Náhan, along the several lines of upheaval. A compromise on similar grounds was made in the prolongation of the Sirmúr zone, on account of the total depression of the bottom nummulitic beds, and the appearance of higher beds, unlike any in the typical area. The paper referred to contains many more details than can be given here.

the similar boulder gravel capping the low hills of the Siwalik beds at Bubhór.

The easiest solution of the case is to accept these Gamrola conglomerates as upper Náhan beds; the fact, that Siwalik conglomerates hold a like relation of apparent conformity to lower Náhan beds in the Bubhór section, being disposed of through the peculiar conditions of deposition and disturbance shewn to have obtained in the Sub-Himalayan region. The case may be either complicated or simplified by the fact that farther north, along the same boundary at Dubrog, as already mentioned, conglomerates of the coarse shingle type are in force. As these descriptions are taken from a very cursory examination of the ground, it is likely that a proper survey will make all clear. Meantime such suggestions as are given may be of service to passing observers.

Doubtful beds in the Sirmur zone.—Our next example is taken from the Sirmúr zone. The structure of this rock-series in its typical ground, the outlier on the Lower Himalayan border, is somewhat different from what it is when forming an inner zone of the Sub-Himalayan area, from immediately north of the Sutlej. In the former position the lowest beds, the Subáthu nummulitics, are always freely exposed in the low ground at the edge of the area, and detached patches occur outside the principal area; whereas the nummulitic beds north of the Sutlej are last found on rather high ground in the middle of the band, in the axis of an anticlinal flexure, and the highest beds of the series appear along the inner junction, dipping at a high angle towards the old rocks of the high mountains. It is so at least till we approach the flanks of the Dhauladhár range. As already explained, this inner Sirmúr line is now the main boundary of the whole section, and its general regularity of direction, combined with the features noticed, is suggestive of faulting. According to the arrangement described, the top beds of all are found at the apex of the curved inner boundary, a little north of the Biás. Between Dráng and Haurbágh soft light grey sandstones, undistinguishable from Siwalik rock, are succeeded by clays and conglomerates. The highest beds are exposed in the hill at Sih, and consist of massive bands of coarse breccia, rather than conglomerate, being composed of large and small angular debris of the cherty limestone and of the pink sandstone occurring in the ridge close by, towards which the conglomerates dip at 40°.

The peculiarly local character of these top deposits is very puzzling. It suggests some almost necessary modification of the simply faulted nature of the boundary, for the proximity to the old rocks at the time of formation must have been somewhat like what it is now. But the

strangest fact is, that although made up entirely of the Himalayan rocks recognisable in the ridge close by to the east, the most abundant rock of that ridge is not represented in the breccia, although in the actual talus of the ridge it asserts its necessary predominance. That rock is eruptive. The suggestion is very strong, that the intrusion of the igneous rock is of later date than these tertiary deposits; and this is the only observation by the Survey confirmatory of that made by General Strachey in Kumaun (see page 543), that the trap-rock of the Lower Himalayas is of tertiary age. No case of intrusion amongst tertiary beds has been noticed in the Biás area, where trap is in great force in the higher hills of Mandi. It is worth mentioning that no debris of tertiary rocks was found in these conglomerates of Sih.

Thus again here, within the inner zone of tertiary rocks, at the main boundary with the old rocks of the Lower Himalayas, and 50 miles from the outer zone of the Siwaliks, there are rocks which confront us as being possibly of Siwalik age; but the presumption is that they are older.

Want of fossils.—That so much disquisition should have been expended upon this difficulty, is already an admission that fossil evidence has hitherto failed us. But even this negative fact must at present have some weight in the argument. There is no recorded case of a fossil being found in these innermost beds of upper tertiary aspect, nor indeed in any upper beds inside the Ghambar fault, although that area includes a large portion of the Kángra district, and the whole of the ground known as the Kángra valley, where for many years Europeans have been accustomed to reside. The greater part of that area, moreover, between the lower tertiary zone and the Ghambar fault, is occupied by rocks which, but for the stratigraphical difficulties mentioned, would be taken at once as equivalents of the accepted Siwaliks of the Bubhór section. Whatever horizon those beds belong to, it may be confidently expected that fossils are to be found in them; but it is well to emphasize the significance that may belong to any organic remains obtained from the Kángra valley.

The base of the Dhauladhar range.—The features of the tertiary contact-zone, on the north of the Kángra district, along the base of the Dhauladhár, present peculiar features of interest. Nowhere else are these late deposits brought so near to the oldest Himalayan rocks. Above the sanitarium of Dharmsála, which stands on the Sirmúr zone, the space is not more than one mile between the tertiaries and the "central gneiss," which rises precipitously in the rugged crest of the Dhauladhár to above 16,000 feet in elevation. As might be expected, the general stratigraphical features are different in such a position from those of the

Lower Himalayan region. The general view suggested at first sight is, that the gneiss occupies the axis of a huge folded flexure, in which even the Siwaliks partook. This view would agree with the opinion sometimes expressed, that the whole Himalayan mountains have been upraised since a late tertiary date; and indeed the prodigious disturbance the tertiary rocks have undergone is sufficient testimony of the great changes that have been effected within that time. It would, however, be most difficult to maintain that the tertiary rocks had ever extended much beyond their present limits. This can at least be asserted for the beds immediately outside the Sirmúr zone: the enormous accumulation of tertiary river-shingle conglomerates along the base of the range west of Bhágsu to beyond the Rávi implies the proximity of an area of erosion to the north.

The case is different for the Sirmúr series; and increasingly so to the west. At Dharmsála these rocks affect a synclinal structure next to the main boundary, but the junction is well defined. At some spots to the west, as along the Chaki, the Sirmúr beds are scarcely, if at all, represented; and at the western extremity of the range, over the Rávi, they are so crushed together with the older rocks as to be inseparable from them, or else so altered as to be unrecognisable. The particular section referred to is at the head of a great fan on the left bank of the Rávi below Simliu, where the Sirmúr beds pass transitionally into a green pseudo-amygdaloidal trappoid rock, very similar to a rock of the Pir Panjál that is currently accepted as trappean. The section is so distinct as to have suggested that the Panjál rock would turn out to be altered Sirmúrs. This conjecture has not been confirmed; but it illustrates the degree to which the lower tertiary rocks are implicated in the structural features of the Dhauladhár. It is worth mentioning that on an outer outcrop in this position, a bed with obscure leaf marks was found, exactly like that of Kasauli, and so far suggesting the integrity of the Sirmúr group.

The Mandi rock-salt.[1]—As it is still a disputed point whether the rock-salt of Mandi belongs to the Sub-Himalayan or the Lower Himalayan rocks, it will be most appropriate to notice it in this section treating of the Kángra district. The rock is known in the country as "black-salt," in contradistinction to the pure mineral of the Salt Range. It has a dark, purplish hue, is quite opaque, and contains about 25 per cent. of earthy matter, the salt itself being nearly pure sodium chloride. It is only used by the poorer classes, after being subjected to a purifying

[1] Mem. G. S. I., III, Pt. 2, p. 60.

process by fire and water. Small nests of crystalline salt occur, but so rarely as to be reserved for the use of the Rajah and his household. The mines or quarries are at Dráng and Guma, 14 miles apart.

The salt occurs in a constant position, at a short distance within the well-defined boundary between the tertiary sandstones and the slaty calcareous rocks, apparently all belonging to the Lower Himalayan series, which are here, on the margin of the Biás basin, in a state of extreme disturbance, with abundant trappean intrusion. Its occurrence in a constant position along the general strike of the associated strata, and the distinct lamination in the rock itself, sufficiently prove its sedimentary origin. But besides the earthy matter, laminated or diffused, the salt commonly contains small angular pebbles, principally of pink quartzite and of limestone, very like the rocks of the adjoining ridge; and where the salt itself is wanting, this character is often found in a calcareous rock in the same position in the section, as in the Sukéti, a few hundred yards above its confluence with the Biás, and again in the Kángra district, in the river east of Bír (Beer).

The presence of these pebbles may have suggested to Mr. Theobald his opinion,[1] that the salt-rock of Mandi and the narrow band of rock between it and the main boundary are of nummulitic age. The fact already mentioned, that the Subáthu nummulitic beds are not found in a recognisable form throughout the greater part of the Sub-Himalayan zone in the Kángra area, gives at least negative support to this conjecture; and positive support may be found in the fact observed in this same area, as mentioned in the preceding section, how the nummulitic rocks here have been to some extent disguised beyond recognition, so as to be more akin in appearance to the old rocks than to their real associates of the tertiary zone.

North-western termination of the Kangra area.—The outer Siwalik range of the Kángra area does not cross the Biás. The second (Parwain) range, also of that region, ends at Pathánkót, east of the Rávi. This extinction in echelon of the outer Sub-Himalayan ranges is structural, and not merely due to denudation. It will be shewn that the termination of the Dhauladhár east of the Rávi is probably of a similar nature, and the coincidence of these homologous features in the newest and oldest rocks in this terminal Himalayan region is noteworthy, although no very direct connexion can be suggested, except that the reduction of dimensions of the mountain-features took place in a like fashion in each zone, whether synchronously or not.

[1] MS. report.

THE JAMU AREA: **boundaries.**—Jamu (Jummoo) is the capital of the Sub-Himalayan territories, and the winter residence, of the Maharaja of Kashmir; and the name may appropriately be taken for this section of the Sub-Himalayan zone, the limits of the area being also very well marked by physical characters.[1] The Jhelum is the western boundary, where its course lies in the axis along which all the strata bend at an acute angle from their Himalayan strike into that of the mountains of Hazára and of the Salt Range, on account of which fact it has been chosen as the limit between the Himalayas proper and the Punjab hill regions, described in the preceding chapter. The west boundary of Jamu is the Rávi, which also coincides with a very marked stratigraphical node.

Special feature.—As the peculiar expansion of the Náhan zone of the Sub-Himalayas in the Kángra area corresponded with the extinction of the Lower Himalayan region, so the most peculiar character of the Sub-Himalayan region of Jamu is the expansion of the Sirmúr zone, taking its rise from the abrupt extinction of the Dhauladhár axis at the Rávi. This inward step of the lower tertiary zone corresponds with that of the outer zone: the two outer Siwalik ranges of the Kángra area having died out, the outermost range of the Jamu area occurs on the prolongation of the Badsar-Nurpúr dislocation.

Sirmur zone at the Ravi.—The change of features from the Kángra to the Jamu area is otherwise so decided, that it is remarkable that the two master-dislocations of the Kángra area—the Ghambar-Basauli and the Badsar-Nurpúr faulted flexures—continue without a check or turn across the Rávi. The contrast they present in this way with the boundaries of the inner tertiary zone is very striking: the Sirmúr band makes two abrupt, nearly rectangular, bends at the Rávi; and the river runs for about 7 miles in a south-south-west direction along, not across, the local strike, where the whole series of formations bends round across the termination of the gneissic axis of the Dhauladhár. The condition of the Sirmúr rocks at their inner contact suggests, as already described, complete participation in the intense contortion of the older rocks; while on the outside, the Sirmúrs are in sharp contrast with comparatively fresh-looking conglomerates. These are enormously thick, but not very coarse, as the upper Siwalik conglomerates always are near the great rivers. Debris of the Sirmúr sandstone occurs in these old conglomerates; but

[1] The maps published with the following papers are on the same scale, and, when joined together, give a fair view of the features noticed in the text:—Sub-Himalayan Country between the Ganges and the Rávi, Mem. G. S. I., III; Jamu and Pir Panjál, Rec. G. S. I., IX; North-West Punjab, Rec. G. S. I., X.

here again it was observed that the pseudo-amygdaloidal trappoid rock is not represented, although it constitutes at present the most abundant detritus at the surface. These outer rocks, too, are greatly disturbed, being for the most part vertical along the south-south-west strike, so that we cannot say that they have not been subjected to the whole disturbing action; and the abrupt contact of beds of very different horizons would suggest faulting. Taking everything into consideration, however, it seems probable that this line of junction is not primarily a fracture, or at least that its form has been determined by local features of the surface, in the same position as those now so conspicuously developed. It is an illustration in this ground of the slow process of growth of the mountain structure, already illustrated from other sections.

Western expansion of Sirmur zone.—The suppressed and disguised condition of the Sirmúr zone is one of the peculiarities of the Sub-Himalayas of Kángra, where the Subáthu (nummulitic) group has not been detected throughout a distance of more than 100 miles south-east of the Rávi. The expansion of this zone and the free exposure of the bottom group, and even of the supporting rocks, are, on the contrary, the most marked features of the Sub-Himalayan area of Jamu. In this last respect the Jamu tract resembles the original Sirmúr area in the Lower Himalayas of the Simla region, except that in the latter instance the tertiary strata lie as outliers on the old rocks of the mountains, whereas in Jamu the old rocks appear as inliers in the Sirmúr zone. This comparison might only imply a relation of degree in the amount of denudation the two areas had undergone; but the case is far otherwise: there is a great difference in the stratigraphical relations of the two rock-series in the east and in the west, confirming in a very marked way the opinions arrived at, from the study of the upper tertiary groups, regarding the growth of the mountain-system. It is also to be particularly remarked that in Jamu as in Kángra, but not in the Sirmúr area, the nummulitic rocks never occur at the inner boundary of the zone.

At the Rávi the Sirmúr band is less than a quarter of a mile wide. It expands gradually to nearly 20 miles at the road from Jamu to Kashmir; at Rajauri it is reduced to 12 miles; and farther on, at the Púnch, it is nearly 30 miles wide. As in the case of the upper tertiaries of the Kángra area, this expansion and irregularity is due to the unsteadiness of the inner (main) boundary—a character which appears to shew that that boundary is more probably due to original[1] features of the ground, than to subsequent faulting; while the outer

[1] See note, p. 528.

boundary is very steady in direction, and is clearly connected with faulted flexures. This latter feature dies out in an anticlinal axis to the north-west of Kotli on the Púnch, before reaching the Jhelum; and to the south-east, except for its concealment at the Biás, it is more or less continuous with the Náhan-Sirmúr boundary of the Simla region, the "main boundary" of the tertiary zone in the middle Himalayan region. This resemblance or even correspondence with the main boundary of the Lower Himalayas east of the Sutlej is further increased by the appearance of the great limestone inliers along this line in Jamu; yet the discussion of the feature in the Simla region seemed to be against its being primarily a fault there.

Within 15 miles of the Rávi, above the village of Marún, over the Pain (Pine) river, a thin calcareous layer with nummulites was observed, high in a thick section of red shaly clays at the outer edge of the Sirmúr zone. The occurrence of even these upper Subáthu beds along this boundary is not, however, constant. On the contrary, something like a regular succession of high and low beds, occupying alternating intervals across the Sirmúr zone, as of waves along the strike, is very observable in the Jamu area. It is well exhibited in connexion with the great inliers.

Inliers.—These protruding masses of old rocks within the Sirmúr zone occur in two pairs: the Lápri and Sangar-Marg ridges on the Chináb, and the Ranjoti and Debigarh ridges near the Púnch. They are formed of hard limestone, conjectured to be of palæozoic age, with subordinate flaggy sandstones, and they stand out high above the surrounding tertiary strata,—a result due proximately to denudation. Lápri has an elevation of 9,914 feet, and seems to be protruded abruptly through the red beds of the Sirmúrs, no distinctively Subáthu beds having been observed near it. Sangar-Marg, 6,676 feet high, is the largest of these inliers, being more than 30 miles long, and 5 to 8 miles wide; the Chináb passes by a deep gorge exactly through its centre, just above Riássi.

Characters of the Subathu group.—The marked character of the bottom Subáthu beds makes it easy to distinguish the base of the tertiary series. The composition of this group in the Jamu area differs from that exhibited where the formation was originally described in the Simla region. In the latter ground the calcareous element is very subordinate and scattered, whereas throughout the Jamu hills all the limestone is concentrated in a steady and purely calcareous band near the base of the group. It is constantly underlaid by a band of carbonaceous shales not found in the Simla region, and often including a coaly layer. Thus it

would be very easy to distinguish lithologically an upper and a lower division of the Subáthu group in this western area. But the most constant rock of all is the pisolitic ferruginous clay already mentioned as the bottom rock in the Subáthu section, an exactly similar bed to which is found in the same position all through the Jamu hills; and the same occurs again in the Salt Range, where, at the east end at least, the nummulitic group is represented by these three bottom bands of the Subáthu group of the Jamu region. This fact is noticed here in order to record a suggestion regarding this peculiar bottom bed: in some respects it very much resembles a form of the high-level laterite of the peninsular area, the differences being easily attributable to contingencies that have affected the Himalayan rocks; its remarkable constancy over so large an area is also a strong point of similarity with the laterite, in which this uniformity, at great distances and when surrounded by very different rocks, is so puzzling a character; and lastly, this Subáthu bottom bed is on the geological horizon, already suggested[1] as probable in the case of the high-level laterite formation of the peninsula, and a similar rock has been already noticed on the same horizon in Guzerat,[2] Kachh,[3] and Sind.[4]

Relation of tertiary to palæozoic rocks.—In Sangar-Marg and in the western inliers the original relations of the tertiary series to the old rocks is fully exposed, and in all it presents itself as perfectly parallel superposition. It is difficult to conceive that a junction of palæozoic and tertiary strata can really be conformable, and a close examination will no doubt reveal some discordance; but it is certain that through all the contortions exhibited in these rocks the same contact beds are found together over large areas, and are, locally at least, quite conformable. This local conformity is exhibited at the very crest of the ridges; so these must be altogether due to disturbance of post-nummulitic date.

At many points all over the Sangar-Marg ridge, the Subáthu bottom bed rests upon a brecciated sandstone, associated with the great palæozoic limestone of the inliers. An ochrey iron ore has been extensively extracted from nests in these shattered top beds of the old formation, having probably been derived by infiltration from the coaly and ferruginous beds below the nummulitic limestone. In this great limestone itself the bedding is

[1] *Ante*, p. 364. The chapter on laterite had unfortunately been printed off before this remarkable confirmatory evidence of the theory there put forward as to the origin of high-level laterite had been recognised.

[2] *Ante*, p. 340.

[3] *Ante*, p. 345.

[4] *Ante*, p. 457.

often very obscure, but with such characteristic junction beds the relations of the two formations are very well seen: how the old limestone, as yet uncontorted, must have formed the floor of the nummulitic deposits, and was brought up and exposed on the axes of great complex anticlinal flexures, the covering beds having been more or less removed during the process of upheaval.

At the north-west angle of Sangar-Marg the axis of one of these flexures is very well seen, the old limestone disappearing under a saddle of the nummulitics, which continue exposed for many miles in the valleys to the west, a middle rib of the old limestone appearing again at two points of the outcrop. Copious hot sulphurous springs occur at Barmandal in the nummulitic coaly beds close to this axis, and again hotter springs at the point of the Ranjoti ridge, on the banks of the Púnch, where a corresponding anticlinal feature is well seen. Along the valley of the Choti Táwi, east of the Chináb inliers, and to the west, in the valley of the Bari Táwi, between the two groups of inliers, much higher beds of the Sirmúr series are found, on the very strike of the older rocks, thus shewing longitudinal undulation of the disturbance, as already mentioned.

Compared with sections of Simla region.—The contrast between the relations of the Subáthu group to the older rocks of the Jamu inliers and of the Simla region is a very noteworthy point in the history of the Himalayan region. The full effect of the evidence depends a good deal upon the identity of the old limestones of the two regions, and upon this, as will be explained, different conjectures have been offered; but even supposing the Jamu rock to be carboniferous, and the Król limestone to be triassic, the difference would still be important. In both areas the parallel superposition shews that the contortion of the old rocks occurred after the deposition of the eocene strata; in the Simla region, however, the nummulitics were deposited close to the limestone, but on beds a thousand feet below its horizon, *i. e.*, on an area where the limestone had been deeply denuded: whereas in Jamu the same nummulitics were laid down evenly over the limestone itself. Supposing the limestones the same, the facts would imply that the eastern area had been for long exposed to denudation as a land surface, while the western had been by some means protected from erosion. Analogous conclusions, as to an earlier elevation of the Lower Himalayan area, have been already strongly suggested from a comparison of the Náhan-Sirmúr and Siwalik-Náhan relations to east and west of the Sutlej.

Doubtful newer rocks of the Sirmur zone.—In the Sirmúr zone of the Jamu hills we have again to encounter a puzzle noticed in the Kángra area. Passing west from the Rávi along the inner (main) boundary, higher beds in the tertiary series are found, not accounted for by difference of

elevation, apparent conformable sequence being observed throughout. At several places in the upper Táwi valley, below the Bindi gap, coarse massive conglomerates are nearly vertical, close along the boundary. The peculiarity of these beds as compared with those noticed in a like position at Sih (page 556) is, that the partially rounded shingle of the Táwi conglomerates, containing some blocks 2 feet in diameter, is made up almost exclusively of bottom tertiary sandstone.

The question whence was derived this ancient tertiary debris, at the present inner edge of the tertiary area, is of much interest. The conglomerates occur just where the river, within 10 miles of its rise on the Kúnd-Kaplás mountain, 14,241 feet high, crosses the main boundary from the north-east. This mountain ridge has not been examined, but all the detritus in the river at present is of metamorphic rocks, and there is no known occurrence of tertiary sandstones to the north of the Sub-Himalayan boundary nearer than the basin of the upper Indus in Tibet. Their sub-angular condition and size give a strong presumption that the blocks of comparatively soft sandstone forming these conglomerates have not travelled far; and these fragments may possibly have been derived from some tertiary rocks exposed by a line of early disturbance in the area to the south. The probability seems, however, in favour of the blocks having come from the northwards, beyond the present main boundary; and what we know of the processes of disturbance in these mountain sections, would admit of a very limited range to this former extension of the tertiary deposits. The rocks at the edge of the supposed tertiary basin may have been slowly, but abruptly, turned up along a monoclinal flexure; as thus indurated and exposed to denudation, their debris may have been laid down in conformable sequence upon their undisturbed main area, until the fracture supervened, which resulted in the present steep contact with the ancient supporting rocks. Or it might be possible to derive these blocks from the exposed top of an anticlinal flexure in a former great spread of these lower tertiaries to the north, possibly continuous with the very similar deposits of the Indus valley in Ladák. Independently of geological considerations, the law of parsimony (to favour the least laborious process) inclines to the former supposition; and in any case it is highly probable that the area of denudation was close by when these conglomerates of coarse sub-angular debris were formed.

The question of the age of these conglomerates of the Sirmúr zone is rendered more difficult in this position from the fact of their containing Sirmúr debris. Independently of this, the great thickness of the series implies a great difference of age (in years) between the top and bottom

beds; and it is evident that under the synchronous *pari passu* operations of disturbance and deposition, as urged for the whole Sub-Himalayan zone, the presence or absence of even great local unconformity is of comparatively little import, and thus some ordinary stratigraphical criterions of relative age fail us here. There are other beds in this zone that would even more directly suggest a much later age than any Sirmúr beds of the standard area; as on the band of depression of the Choti Táwi, there is a considerable thickness of soft pale clays north of Chinéni, more like upper Siwaliks than anything else. They are topmost beds, but in apparent sequence with all the other strata of the Sirmúr zone. It would be very rash at present to say that any of these rocks are Siwalik; yet it is seemingly awkward to include, as Sirmúr, beds made up of middle Sirmúr debris. Fossils only can decide these questions, and as yet none have been found in these beds.

Other general features of Sirmur zone.—Such very fresh looking rocks as those on the Chota Táwi have not been observed elsewhere in the Sirmúr zone of this area, but large portions of the ground have not even been traversed. On the Chináb section only low red beds are exposed, higher beds prevailing again on the Rajauri section. The course of the Jhelum in the Sirmúr zone below Uri is with the strike of the rocks, along a broken anticlinal, having the usual upthrow to the north. A continuation of this feature is traceable southward towards Rajauri; and east of the dislocation, in the ridge of the Háji Pir, there is an outcrop of Subáthu limestone. The principal deformity of the direction of the main boundary is north of Rajauri, where there is a broad angular projection of the rocks of the Pir Panjál; it is in such positions that test sections of the true nature of the contact are most likely to be found.

No study has yet been made of that remarkable feature at Musafarábád, close to the confluence of the Kishenganga and the Jhelum, where the main boundary, with the strike of all the rocks and the course of the Jhelum, bend at an acute angle (35°) from the direction of the Himalayan ranges. The position seems approximately coincident with the introduction or expansion of the nummulitic limestone to the westward; and for some little distance on the Himalayan side of the bend this rock occurs at the boundary. Such coincidences of original with induced stratigraphical characters are often very suggestive of correct interpretations. To the south-west of this point, in the Hazára hills, the whole character of the bottom tertiary zone is changed: instead of a continuous main boundary, separating all the tertiary deposits from the rocks of the higher range, as in the Himalayan region, we find the nummulitic beds folded up promiscuously with the underlying

formations, resulting in a very patch-work appearance of the outcrops, as shewn in a map. Thus the nearest physical equivalent of the main boundary of the Sub-Himalayas should be near Abbottabad rather than near Murree.[1] This contrast might, of course, be due simply to greater elevation and denudation of the western area; but it is probably further connected with other original points of difference between the two areas, besides the one already mentioned: in the trans-Jhelum ground other formations (jurassic and triassic) are introduced between the Subáthu group and any representative of the palæozoic limestone of the Jamu inliers.

The Siwalik-Sirmur boundary.—Pending the palæontological determination of the equivalent horizons in these several zones of similar rocks, little more can be done than to describe these mere rock-features. The outer boundary of the Sirmúr zone of the Jamu area, on the prolongation of the main boundary of the Lower Himalayan region, has already been noticed as mainly a fault-line. This is strongly suggested by the straightness of the feature; and everywhere along it, beds of different horizons are in contact, till at last, within a few miles of the Jhelum, it dies out in an expanded anticlinal flexure, where again, as on the Biás, one can pass from the Siwalik to the Sirmúr zone without a break. Thus this feature, whether dislocation or not, of principal magnitude and persistence throughout the whole Himalayan border, comes to an end within the Himalayan limits, not like the more simple features of disturbance, recognised as primarily faults or flexures, which are continuous with like features beyond the Jhelum. There is one remarkable irregularity of this boundary at the Chináb; and the normal direction of the Siwalik zones undergoes a corresponding deflection in this position. At Riássi, where the river passes through the Sangar-Marg inlier, there is a wide bay in the south face of the limestone ridge, making a very marked indent in the course of the outer Sirmúr boundary.

The Basauli-Naushera fault.—On the Rávi, where a much more abrupt twist affects the inner tertiary (Sirmúr) zone, it was noted that the great dislocations in the Siwalik zone swept past it with little or no deviation. It is not so at the Chináb: the Ghambar-Basauli fault curves northwards into apparent, or actual, continuity with the eastern face of the Riássi bay, thus cutting off the inner Siwalik zone of Udampur and Kángra. This effect is, however, not permanent, for an equivalent dislocation emerges in continuity with the western side of the bay,

[1] In the North-West Punjab Map, referred to in the note, p. 560, the boundary west of the Jhelum, continuous with the main boundary to the east, is probably a junction of upper and lower Subáthu beds.

and forms the Naushera faulted anticlinal, with the Kotli synclinal dún between it and the Sirmúr zone, representing the Udampur dún to the east. The Naushera dislocation is as important as its eastern representative; it curves round across the Jhelum, north of Mount Narh, passing south-westwards towards Ráwalpindi.

Riassi conglomerates.—The actual continuity of this Basauli-Naushera dislocation, round the edge of the Riássi bay, may possibly be maintained. There are no observations to settle the point, or to shew the relation of this dislocation with the outer Sirmúr boundary, where the two are confluent at the base of Sangar-Marg. Thus it would seem that the conglomerates on the Chináb, in the Riássi bay, belong as much to the middle as to the inner Siwalik zone; and there is strong presumption that they correspond in age to the conglomerates of the inner zone on the Rávi, north of Basauli. In both cases the conglomerates occur in force only near the great rivers.

The outer Siwalik zone.—The Riássi bay is most marked in the outer Siwalik zone. The Badsar-Núrpúr anticlinal, which is a conspicuous feature throughout the lower hills of Jamu to beyond the Jhelum, where it bends south-westwards to Kahúta, makes a deep swerve northwards at the Chináb, so that the outermost Siwalik range north of Jamu runs due north and south for some distance. This corroborates the suggestion that the Basauli-Naushera dislocation does actually run up to the inner boundary under Sangar-Marg. The elucidation of this very exceptional feature, in connexion with the great inlier, would form an interesting study.

Outside the Badsar-Núrpúr flexure there is no great continuous dislocation passing across the Jhelum from one direction of strike into the other, as in the deeper sections to the north: a number of local independent flexures pass off more or less obliquely from the Himalayan strike, to terminate in a reciprocating manner with the flexures of the Salt Range system.[1] This arrangement exhibits, in even a more convincing manner, a synchronous action in both directions of disturbance. In this struggle for room the Salt Range system seems to have had the best of it: flexures belonging to it are more persistent in overlapping the Himalayan series. The last example of this is the Pabbi or Kharián anticlinal ridge, consisting of Siwalik rocks, striking due north-east close up towards, and at right angles to, the Sub-Himalayan ranges at Bhimbar; its prolongation for 18 miles would thus strike the great Siwalik dislocations on the Bari Táwi, more than 50 miles from their diversion on the Jhelum. This outlying Kharián flexure is altogether east of the

[1] See maps quoted in note, p. 560.

Jhelum, and forms the only exception to this river forming an exact boundary of the Sub-Himalayan system.

SUMMARY.—As other considerations made it necessary or desirable to break up the description of the Sub-Himalayan zone into sections of areas more or less natural or arbitrary, we must now endeavour to indicate connectedly the chief points of evidence upon which inferences have been based regarding the history of the mountains.

1. Special Himalayan disturbance altogether post-eocene.—Where the original relations of the lowest tertiary deposits, the Subáthu nummulitic group, to the very ancient (palæozoic) rocks of the mountains are exposed in the Simla region (p. 532) and in Jamu (p. 563), we learn that these old rocks had then undergone no contortion, where now contortion is extreme. We might thus infer that the Himalayas, *as a region of special disturbance*, had then made no beginning, and for this southern zone of the mountains this inference is conclusive; but there are other facts to qualify it as regards an earlier stage of Himalayan elevation.

2. Eocene Himalayan land.—The remnant of lowest tertiary rocks preserved on the margin of the Lower Himalayas in the Simla region, reveals other original relations not elsewhere discoverable—(*a*) the old rocks had here been deeply denuded (p. 533), as by subaërial denudation; (*b*) the Subáthu beds here are very variable in thickness (p. 533), suggesting proximity to a limit of deposition to the north-east; (*c*) the marked deficiency in these Sub-Himalayan nummulitics of open sea deposits or organisms (p. 531) suggests at least estuarine conditions; (*d*) the regular succession here of deposits of true Sub-Himalayan type (pp. 525, 530) carries on this suggestion, implying that before any special contorting action had set in, the general conditions of Sub-Himalayan deposition had been established by a general (continental) elevation of the Himalayan area. The presence of terrestrial plants in the Kasauli beds also proves the proximity of land.

3. Doubtful extension over the Lower Himalayan area.—Even in the Simla region, the border of that eocene Himalayan land is only approximately and conjecturally indicated. The inner boundary of this Sirmúr outlier is quite different from any line of junction in the Sub-Himalayan zone (p. 534): these latter are universally, to some extent or other, special features of Himalayan disturbance, forming single continuous lines of boundary; whereas the former is the outcrop of an irregular surface of deposition that had subsequently undergone simple corrugation and denudation. As regards the country to the north-west, the absence in the old rocks of Jamu (p. 564) of the denudation which is so marked in the Simla region, suggests that the long pre-

tertiary elevation of the Lower Himalayan region had not extended to the north-west. The features of the boundary in this direction also leave it an open question how far the tertiaries may have extended: we find these either amalgamated with the older rocks in their most extreme condition of disturbance (p. 558), or in abrupt faulted contact (p. 565), both states implying some former extension; so there remains only the fact of composition to suggest that there, too, there was a neighbouring eocene land.

4. Actual Himalayan border defined in middle tertiary times.—To the east of the Simla region the case is the reverse of that described to the west: no trace of lowest tertiary rocks has been found in the Sub-Himalayan zone in this direction (p. 534); the Sirmúr rocks seem to have been uplifted, and more or less completely removed by denudation, in early tertiary times (pp. 534, 540), when the present Himalayan border was defined. The only connection suggested for the Subáthu group in the east is the strikingly similar nummulitic beds in the Gáro hills, at the west end of the Assam range (p. 535).

5. Its partial extension to the north-west.—This first great act of Himalayan disturbance in tertiary times, as just recorded, again resulted in the elevation of the Lower Himalayan as compared with the north-western area, producing the Náhan-Sirmúr unconformity, and the main boundary of the whole middle Himalayas. In the north-west the Náhan-Sirmúr boundary is the most important structural feature within the Sub-Himalayan zone; and there, too, it is doubtfully a feature of simple dislocation (pp. 560-1). The elevation in the east seems to have taken place earlier: seemingly newer rocks occur in the Sirmúr zone north of the Sutlej than in the Simla region (p. 556).

6. Himalayan river-gorges in Siwalik times same as now.—The great accumulation of conglomerates, and their marked variation in quantity and quality in relation to the great Himalayan torrents, are most marked in the outer Siwalik zone (pp. 541, 551); and the fact admits of no other explanation than that the gorges of these torrents in the adjoining mountains were then in the same positions as now, and have not been sensibly changed by the prodigious disturbance to which these latest Siwalik deposits have been subjected (pp. 541, 551). In the north-west similar accumulation and distribution of conglomerates are found in the inner Siwalik zones (p. 568). Whether or not these prove to be of the same age as those on the outer zone on the same section, the fact is again suggestive of the earlier elevation and separation of the zones in the middle Himalayas.

7. Extreme slowness of disturbing action.—The extreme slowness with which such great operations of disturbance were accomplished

is sufficiently attested by the fact related in the preceding paragraph regarding the great rivers; the inference being especially illustrated by the case of the Sutlej at Bubhór (p. 551). This case illustrates, too, a constant puzzle in these Sub-Himalayan sections—the close conformable sequence between strata that were virtually strongly discordant. The same process of simultaneous deposition and disturbance gives us some explanation of the prodigious thickness of these deposits—a thickness that would appear excessive if the measurements had to be understood as vertical dimensions.

8. Elevation preceded compression.—One important inference upon the theory of mountain-formation is apparent from these observations on the Sub-Himalayan zone. Special Himalayan disturbance is now nowhere more strongly marked than in this fringing zone; and it has all occurred since a middle tertiary date, for the oldest rocks were then unplicated in this position. Yet a considerable Himalayan elevation had occurred in pre-tertiary and early tertiary times; and this elevation must, therefore, have been of the nature of a simple protuberance *(bossellement)*, or warp, as suggested in De Beaumont's theory of mountain-formation; while some more modern theories seem to require that compression with contortion should be a first stage in the process of special elevation.

CHAPTER XXIV.

EXTRA-PENINSULAR AREA.

SIWALIK FAUNA.

The later tertiary vertebrate fauna — Siwalik mollusca — Homotaxis of mammalia — Reptilian evidence — Siwalik fauna probably pliocene — Stratigraphical evidence of age of Siwaliks — Survival of miocene forms in Siwalik beds — Pliocene fauna of Pikermi in Attica — Migration — Effects of change of climate — Comparative poverty of recent mammalian faunas — Relations of Siwalik to Perim Island fauna — Comparison with Irawadi fauna — Comparison of Siwalik and recent faunas.

The later tertiary vertebrate fauna.—In several of the preceding chapters reference has been made to the mammalian fauna found in the upper tertiary beds of Northern and Central India, and in five instances,—the post-pliocene faunas of the Gangetic plain [1] and of the Narbada valley,[2] the older pliocene mammalia of Perim Island,[3] and the miocene faunas of Sind[4] and of Kushalghar[5] in the Punjab,—lists of the species identified have been given. By far the most important collection of mammalian remains found in any Indian formation is, however, that of the Siwalik beds; and as many of the species found elsewhere recur in the Siwalik area of the North-West Provinces and the Punjab, it will be useful in the present chapter to give a general account of the later tertiary vertebrata of India and Burma.[6] The following is a complete list of all species[7] hitherto identified in the miocene, pliocene,

[1] *Ante*, p. 402.
[2] P. 385.
[3] P. 343.
[4] P. 471.
[5] P. 514.

[6] Crania and teeth of several species, and in two instances, *Astragali*, are figured in Plates XVII, XVIII, XIX, and XX. References are appended in the list of species.

[7] The majority of the tertiary vertebrata of India, discovered by Falconer, Cautley, Baker and Durand, were described by Falconer, most of whose writings, published and unpublished, are collected in his posthumous "Palæontological Memoirs." The greater portion of the following notes are taken from Mr. Lydekker's papers on the Siwalik fauna; Rec. G. S. I., IX, pp. 42, 86, 144, 154; X, pp. 30, 76, 225; XI, p. 64; and Pal. Ind., Ser. X, Pts. 2 and 3; and from some MS. papers by Mr. Theobald, who has collected a large number of the fossils described by Mr. Lydekker.

and post-pliocene deposits of British India and its dependencies, the distinctly miocene forms of Sind and the Punjab being distinguished by the letter M, and the post-tertiary mammals by Pl being affixed. To all forms that have been found in the Siwalik area, irrespective of horizon, the letter S is added; the species from Perim Island are distinguished by a P, and those from the Irawadi valley by I.

MAMMALIA.

PRIMATES.

S. *Macacus sivalensis.*
S. *M.*, sp.
S. *Semnopithecus*, sp.
S. *? Semnopithecus subhimalayanus*, Pl. XIX, fig. 11.
Pl. *S.*, sp.

CARNIVORA.

FELIDÆ—
S. *Felis cristata.*
S. *F. palæotigris.*
Pl. *F.*, sp.
S. *Machærodus sivalensis.*
S. *Pseudælurus sivalensis.*

VIVERRIDÆ—
S. *Ictitherium sivalense.*

HYÆNIDÆ—
S. *Hyæna sivalensis*, Pl. XIX, figs. 8, 10.

CANIDÆ—
S. *Canis (Vulpes)*, sp.

URSIDÆ—
S. M. *Amphicyon palæindicus*, Pl. XIX, fig. 4.
S. *Ursus*, sp.
I. *U.*, sp.
Pl. *U. namadicus*, Pl. XX fig. 6.
S. *Hyænarctus sivalensis*, Pl. XIX fig. 9.
S. *H. palæindicus.*

MUSTELIDÆ—
S. *Mellivora sivalensis.*
S. *Meles*, sp.
S. *Lutra palæindica.*
S. *Enhydriodon sivalensis*, Pl. XIX, fig. 5.

PROBOSCIDEA.

ELEPHANTIDÆ—
S. *Elephas (Euelephas) hysudricus*, Pl. XVII, fig. 5.
Pl. *E. (Euelephas) namadicus*, Pl. XX, figs. 5, 8.
S. *E. (Loxodon) planifrons.*
Pl. S. *E. (Stegodon) insignis*, Pl. XVII, figs. 1, 7.
Pl. S. *E. (Stegodon) ganesa*, Pl. XVII, fig. 2.
S. *E. (Stegodon) sinensis.*
S. *E. (Stegodon) bombifrons.*
S. I. *E. (Stegodon) cliftii.*
S. I. *M. (Pentalophodon) sivalensis*, Pl. XVII, fig. 6.
S. I. P. M. *Mastodon (Tetralophodon) latidens*, Pl. XVII, fig. 4.
S. P. M. *M. (Tetralophodon) perimensis*, Pl. XVII, fig. 3.
Pl.? *M. (Trilophodon) pandionis.*
S. M. *M. (Trilophodon) falconeri.*

DINOTHERIDÆ—
P. *Dinotherium indicum.*
M. *D. pentepotamiæ.*

UNGULATA.

A. PERISSODACTYLA.

RHINOCEROTIDÆ—

S. *Rhinoceros platyrhinus.*
S. M. *R. sivalensis,* Pl. XIX, figs. 1, 3.
S. M. *R. palæindicus.*
S. *R. planidens.*
I. *R. iravadicus,* Pl. XIX, fig. 2.
Pl. *R. namadicus,* Pl. XX, fig. 9.
Pl. *R. deccanensis.*
S. *R.* 2 sp.
I. *R.* sp.
M. *R.* 2 sp.
S. P. I. *Acerotherium perimense.*

TAPIRIDÆ—

I. *Tapirus,* sp.
M. *Listriodon pentepotamiæ,* Pl. XIX, fig. 7.
S. *L. theobaldi.*

EQUIDÆ—

S. *Equus sivalensis.*
S. *E. palæonus.*
I. *E.* sp.
Pl. *E. namadicus,* Pl. XX, fig. 4.
S. *Hipparion antelopinum,* Pl. XIX, fig. 6.
S. M. *H. theobaldi.*

B. ARTIODACTYLA.

HIPPOPOTAMIDÆ—

Pl. *Hippopotamus* (*Tetraprotodon*) *palæindicus,* Pl. XX, fig. 7.
S. *H.* (*Hexaprotodon*) *sivalensis,* Pl. XVIII, figs. 1, 6, 8.
I. *H.* (*Hexaprotodon*) *iravadicus.*
Pl. *H.* (*Hexaprotodon*) *namadicus,* Pl. XX, fig. 2.
S. *Hippopotamodon sivalensis.*

TETRACONODONTIDÆ—

S. *Tetraconodon magnus.*

SUIDÆ—

S. *Sus giganteus,* Pl. XVII, fig. 9.
S. *S. punjabiensis.*
S. P. M. *S. hysudricus.*
Pl. *S.* sp.
M. *Sanitherium schlagintweiti.*
S. *Hippohyus sivalensis,* Pl. XVII, fig. 8.
S. *H.* sp.
M. *Hyopotamus palæindicus.*

ANOPLOTHERIDÆ—

S. *Chalicotherium sivalense,* Pl. XVIII, fig. 4.

ANTHRACOTHERIDÆ—

M. *Hyotherium sindiense.*
S. I. *Merycopotamus dissimilis,* Pl. XVII, fig. 10.
M. *Anthracotherium silistrense.*
Chæromeryx silistrensis.
M. *Hemimeryx,* sp.
M. *Sivameryx,* 2 sp.

CERVIDÆ—

S. *Cervus latidens.*
S. *C. triplidens.*
S. *C. simplicidens.*
Pl. *C. namadicus.*
I. *C.* sp.
S. M. *Dorcatherium majus,* Pl. XVIII, fig. 3.
S. M. *D. minus.*

CAMELOPARDALIDÆ—

S. *Camelopardalis sivalensis.*
S. *C.* sp.
P. *C.* sp.
S. *Sivatherium giganteum,* Pl. XVIII, fig. 7.
P. *Brahmatherium perimense,* Pl. XVIII, fig. 5.
S. *Hydaspitherium megacephalum.*
S. *H. grande.*
S. *H. leptognathus.*
I. *Vishnutherium iravadicum.*

B. ARTIODACTYLA—continued.

BOVIDÆ—

S. *Bos acutifrons.*
S. *B. planifrons.*
S. *B. platyrhinus.*
I. *B.*, sp.
Pl. *B. namadicus*, Pl. XX, fig. 3.
S. *B.* (*Bison*) *sivalensis.*
Pl. S. *B.* (*Bubalus*) *palæindicus*, Pl. XX, fig. 1.
S. *B.* (*Bubalus*) *platycerus.*
S. *Peribos occipitalis.*
S. *Amphibos acuticornis*, Pl. XVIII, fig. 2.
S. *Hemibos triquetricerus*, Pl. XVIII, fig. 1.
S. *Antilope sivalensis.*
S. *A. patulicornis.*
S. *A. porrecticornis.*
S. *A. palæindica.*
P. *A.* sp.
Pl. *A.* sp.
S. *Capra sivalensis.*
S. *C.* sp.
P. *C. perimensis.*
S. *Ovis*, sp.

CAMELIDÆ—

S. *Camelus sivalensis.*

RODENTIA.

MURIDÆ—

S. *Mus*, sp.
Pl. *M.* sp.

SPALACIDÆ—

S. *Rhizomys sindiensis.*

HYSTRICIDÆ—

S. *Hystrix sivalensis.*

EDENTATA.

M *Manis sindiensis.*

AVES.

S. *Argala falconeri.*
S. Other bones belonging to the order *Grallæ.*

REPTILIA.

CROCODILIA.

S. *Crocodilus crassidens.*
S. *C. leptodus.*
S. *C. palustris.*
P. *C. perimensis.*
M. *Crocodilus*, sp.
Pl. *C.* sp.
I. *C.* sp.
S. I. *Gharialis gangeticus.*

LACERTILIA.

S. *Varanus sivalensis.*

OPHIDIA.

S. M. *Vertebræ* indet.

CHELONIA.

S. I. *Colossochelys atlas.*
S. I. *Testudo*, sp.
S. *Bellia sivalensis.*
Pl. S. *Emys tectum.*
S. *E.* (*Batagur*), sp.
Pl. *Emys* (*Batagur*), cf. *dhongoka.*
S. I. *Emyda*, sp.
S. I. *Trionyx*, sp.
Pl. *T.* sp. cf. *gangeticus.*

Siwalik mollusca.—The few mollusca which have been found belong solely to fresh-water or terrestrial forms, and the only comparison hitherto made[1] was carried out under circumstances so unfavourable, with so poor a collection of recent species from India, and at a time when the latter were so imperfectly known, that but little weight can be attached to the conclusions formed. No good materials for comparison have been procured of late years, and the few specimens obtained are in poor preservation, but all the forms collected since the recent fresh-water shells have been better known have proved to be either identical with living species, or closely allied to them. Amongst those hitherto identified, the only land-shell is *Bulimus insularis*,[2] a species which ranges at the present day from Africa to Burma, whilst amongst fresh-water mollusks, the two common Indian river-snails, *Paludina bengalensis* and *P. dissimilis*, have been recognised, and forms of *Melania*, *Ampullaria*, and *Unio* also occur.

So far as the evidence extends, therefore, the few mollusca of the Siwaliks tend to shew that the beds must be of late tertiary date; for it is difficult to conceive that no important change in the species of fresh-water mollusca would have taken place had the strata been of miocene age. But the evidence afforded by the mollusca is imperfect, and both closer comparison and a larger series of fossil specimens are desirable before any very positive assertions can be made as to the antiquity of the formations on the data afforded by the *Invertebrata*. In investigating the question of age, we are consequently forced to depend, *first*, upon the *Vertebrata*, and especially the *Mammalia*; and *secondly*, upon such geological evidence of connection with other formations of known age as the rocks afford.

Homotaxis of mammalia.—The first question, then, is the homotaxial relation of the Siwalik mammalian fauna. The preceding lists, it should be repeated, embrace the whole of the collections of *Vertebrata* from the later tertiary beds of India; in dealing with the Siwaliks alone, we have therefore to omit all forms found solely—(1) in the lower Manchhar beds of Sind, and their probable representatives in the

[1] Prof. E. Forbes, in Falconer's Palæontological Memoirs, I, p. 389.

[2] Theobald, MS. As in this and the following paragraph Mr. Theobald's view of the affinities of the Siwalik mollusca has been accepted in preference to the high authority of Prof. E. Forbes, it is only just to say that Mr. Theobald has a far more extensive knowledge of living Indian fresh-water shells than it was possible for any naturalist in Europe to acquire at the period when Prof. E. Forbes' note was written. Indeed it is evident from Prof. Forbes' remarks that the collections of recent Indian shells examined by him were too imperfect to enable him to form a competent opinion. Mr. Benson, a far better authority on this particular subject than Prof. E. Forbes, considered the most, if not the whole, of the Siwalik mollusca identical with existing species: Falconer, Pal. Mem., I, pp. 26, 181.

Western Punjab;—(2) in the localities of Perim Island, the Irawadi valley, and certain beds of Sylhet;—and (3) in the post-tertiary clays and gravels of the Jumna, Narbada, Godávari, and other Indian rivers, so far as all such forms are unrepresented in the Siwalik area. This leaves a fauna composed of the following 45 genera, each represented by the number of species noted, the total number of specific forms being 84: extinct genera are marked with an asterisk:—

PRIMATES—

Macacus, 2; *Semnopithecus*, 2.

CARNIVORA—

Felis, 2; *Machærodus** (*Drepanodon*), 1; *Pseudælurus*,* 1; *Ictitherium*,* 1; *Hyæna*, 1; *Canis* (*Vulpes*), 1; *Amphicyon*,* 1; *Ursus*, 1; *Hyænarctus*,* 2; *Mellivora*, 1; *Meles*, 1; *Lutra*, 1; *Enhydriodon*,* 1.

PROBOSCIDEA—

Elephas, 7; (*Euelephas*, 1; *Loxodon*, 1; *Stegodon*,* 5;) *Mastodon*,* 4. (*Pentalophodon*,* 1; *Tetralophodon*,* 2; *Trilophodon*,* 1).

UNGULATA PERISSODACTYLA—

Rhinoceros, 6; *Acerotherium*,* 1; *Listriodon*,* 1; *Equus*, 2; *Hipparion*,* 2.

UNGULATA ARTIODACTYLA—

Hippopotamus (*Hexaprotodon**), 1; *Hippopotamodon*,* 1; *Tetraconodon*,* 1; *Sus*, 3; *Hippohyus*,* 2; *Chalicotherium*,* 1; *Merycopotamus*,*1; *Cervus*, 3: *Dorcatherium*,* 2; *Camelopardalis*, 2; *Sivatherium*,* 1; *Hydaspitherium*,* 3; *Bos*, 6; (*Bos* restricted, 3; *Bison*, 1; *Bubalus*, 2;) *Peribos*,* 1; *Amphibos*,* 1; *Hemibos*,* 1; *Antilope*, 4; *Capra*, 2; *Ovis*, 1; *Camelus*, 1.

RODENTIA—

Mus, 1; *Rhizomys*, 1; *Hystrix*, 1.

Of a large proportion of the species only very imperfect information exists as to the exact horizon in the Siwalik series at which the bones have been found, but the great majority are from the upper and middle Siwaliks, none in the typical area being known to occur in the lower or Náhan sub-division. It is, however, by no means certain that some of the specimens from the North-Western Punjab are not derived from beds of the same age as the Náhan group. The mammals of Kushalghar have already been excluded from the list, because they, like the lower Manchhar species of Sind, evidently belong to an older formation than the fossiliferous portion of the Siwalik beds; and Núrpúr in the Punjab, the only other locality, besides Kushalghar and the Laki hills of Sind,

whence *Amphicyon* has been obtained, may also be upon older strata. It is highly probable that some other forms with middle tertiary affinities would be found to be confined to lower Siwalik beds, if the precise horizon of all the bones collected were known.[1]

On the other hand, one post-tertiary form, *Bos* (*Bubalus*) *palæindicus*, has been found in the highest Siwalik strata, associated with *Camelus sivalensis*, *Colossochelys*, &c.; and two species of elephant belonging to the sub-genus *Stegodon*, viz., *E. insignis* and *E. ganesa*, range throughout the upper Siwaliks, and recur in the post-tertiary deposits. The species of proboscidians generally appear to have had a more extensive range, both in space and time, than most of the forms belonging to other mammalian orders; but *Bos palæindicus* is an animal of exceptionally recent aspect, even in the post-tertiary mammalian fauna, since it is only distinguishable from the living *Bos bubalus* (*Bubalus buffelus* v. *B. arni*, auct.) by comparatively trifling and unimportant osteological details; it must evidently have been a very near ally, and, in all probability, the not very distant progenitor of the buffaloes which now inhabit the Ganges valley, Assam, and parts of the Central Provinces of India.

The Siwalik forms, however, which might be excluded on account of belonging to an older or a newer fauna, and of being supposed, on more or less strong evidence, to be confined to either the lowest or the uppermost portions of the series, are too few in number to affect the general facies, and there are unquestionably several miocene types and some post-tertiary species found in the highly fossiliferous upper Siwalik beds. It is best therefore, for the present, to include all the forms enumerated.

Proceeding, then, to classify the genera above given, it will be found that 24, comprising 53 species, still exist (the living species being however all, so far as is known, different), whilst 21, with 30 species, are extinct. If, instead of reckoning the larger genera, *Elephas*, *Mastodon*, *Hippopotamus*, and *Bos*, their sub-genera are counted, the result will be slightly to diminish the proportion of recent genera, the recent generic types becoming 26, with 47 species, the extinct 25, with 36 species. The former plan of classification is however, on the whole, preferable, because such distinctions as those between *Euelephas*, *Loxodon*, and *Stegodon*, for instance, are scarcely of generic value, the majority of the genera named, e. g., *Felis*, *Rhinoceros*, *Cervus*, *Antilope*, have not been sub-divided

[1] A very large proportion of the Siwalik remains have been obtained by native collectors employed in the search, and of course the precise locality of the bones is in most cases doubtful.

like *Elephas* and *Bos;* and the affinities of the fauna are best understood by grouping the forms in somewhat larger sub-divisions than the sub-genera of older and the genera of many modern writers.

Taking the extinct genera first, the following ten are peculiar to the Indian tertiaries, so far as is hitherto known :—

CARNIVORA—
Enhydriodon.

UNGULATA ARTIODACTYLA—
Hippopotamodon, Tetraconodon, Hippohyus, Merycopotamus, Sivatherium, Hydaspitherium, Peribos, Amphibos, Hemibos.

Of the remaining eleven genera, four, viz., *Pseudælurus, Amphicyon, Listriodon,* and *Dorcatherium,* are only known in Europe from miocene beds, *Pseudælurus* being also found in pliocene rocks in America; whilst *Machærodus, Hyænarctus, Ictitherium, Mastodon, Acerotherium, Chalicotherium,*[1] and *Hipparion* are both miocene and pliocene; the first and fourth ranging into post-pliocene beds also; the former in Europe, the latter in America.

Of the other extinct forms, two, *Hippohyus* and *Merycopotamus,* belong to the less specialised types characteristic in general of the older and middle tertiaries. Several others, such as *Tetraconodon,* with its enormously developed premolar teeth, and the huge four-horned *Sivatherium,* differ widely from anything now existing; but being highly specialised forms, there is nothing in their organisation to indicate that they are of earlier age than newer tertiary.

Amongst the recent genera represented in the Siwaliks, eight, viz., *Felis, Hyæna, Canis, Lutra, Rhinoceros, Sus, Cervus,* and *Antilope,* are known to range as far back as upper miocene, and in one or two cases even further; ten, viz., *Macacus, Semnopithecus, Ursus, Elephas, Equus, Hippopotamus, Camelopardalis, Bos, Hystrix,* and *Mus,* are known from the European pliocene beds, but not earlier; and several are poorly represented, or only known in newer pliocene strata; whilst the following, *Mellivora, Meles, Capra, Ovis, Camelus,* and *Rhizomys,* have hitherto only been found recent, or in post-pliocene deposits.

This examination of the relations between the Siwalik genera and the distribution of similar forms in European tertiaries leads, as might be anticipated, to a somewhat uncertain result. The proportion of living to extinct genera is greater than is found in most miocene deposits, but not more than appears to exist in the characteristically middle tertiary

[1] *Acerotherium* and *Chalicotherium* are found in pliocene beds at Pikermi: see page 583. *Ictitherium* occurs in the pliocene of Pikermi, and in miocene beds in Bessarabia and in France.

ossiferous beds of Sansan in France.[1] The presence of four extinct genera not known to range above the miocene period elsewhere is contrasted with the occurrence of sixteen genera not found elsewhere at a lower horizon than pliocene or post-tertiary. There is perhaps rather more probability that early forms like *Chalicotherium* and *Amphicyon* should have survived longer in India than they did in Europe, just as rhinoceroses, tapirs, and elephants still exist in the tropics, associated with a fauna amongst which they appear antiquated and out of place, than that such eminently specialised types as *Macacus, Bos, Capra,* or *Equus* should have lived in miocene times; but the argument is of small value, for the miocene *Cervus* and *Antilope* were in all probability as highly specialised, or nearly so, as the Siwalik genera. The fact, however, that the recent genera contain more species than the extinct forms is of some importance, since it is probable that types which were dying out would be represented by fewer species than those which were supplanting them, and which might fairly be credited with the vitally important power of producing distinct specific stocks by variation. A stronger argument for the newer age of the Siwalik beds is to be found in the close approximation between some of the mammals and the living species of the same genera, the most remarkable of all being the connection, already noticed, between the fossil buffalo of the uppermost Siwalik strata, that of the post-pliocene Jumna and Narbada beds, and the common Indian species now existing.

Reptilian evidence.—The evidence afforded by the few species of reptiles sufficiently known to be of importance is decidedly in favour of attributing to the Siwalik beds a later age than miocene. Only six species are sufficiently well known to be fairly comparable, and three of these, *Crocodilus palustris, Gharialis gangeticus,* and *Emys tectum,* are common living forms now inhabiting the same area; whilst *Emys* (*Bellia*) *sivalensis*[2] is very closely allied to a living Burmese species, *E. crassicollis.* *Crocodilus crassidens* and *Colossochelys atlas* differ considerably from all living forms, and *Crocodilus leptodus* is very imperfectly known.

Siwalik fauna probably pliocene.—Putting together the whole data derived from *Mammalia, Reptilia,* and *Mollusca,* it is impossible to deny that the balance of evidence is in favour of a pliocene age. This is opposed to the general consensus of European geologists hitherto,[3] and it

[1] Gervais, Zool. Pal. Franc., p. 338.

[2] Theobald, Rec. G. S. I., X, p. 43.

[3] It appears at first sight, also, to be in direct opposition to Dr. Falconer's conclusions, but a study of his writings leaves it doubtful whether he ever expressed any decided conviction on the subject. He repeatedly noticed the close connexion between some Siwalik

would therefore be put forward with very little confidence if it were not supported by some stratigraphical data. As the approximate age of the Siwalik rocks is a necessary element in any argument founded upon their fauna, it will be best to shew how the stratigraphical evidence supports the view that these beds are of pliocene and not of miocene age, before proceeding to notice some other interesting points of connexion between the Siwalik and other faunas, recent and extinct.

Stratigraphical evidence of age of Siwaliks.—The stratigraphical data as distinguished from the purely homotaxial relations just discussed depend entirely upon the connexion between the typical Siwaliks and the Manchhar beds of Sind. The position of the latter has been already described in Chapter XIX,[1] where it was shewn that the whole of the Manchhar group, comprising, where thickest, but little less than 10,000 feet of strata, rests upon the miocene Gáj group, the age of which is determined by the far more satisfactory data afforded by marine organisms, and is shewn to be more probably upper than lower miocene. The lower Manchhar beds pass down into the Gáj rocks, so that it is reasonable to believe that no difference of age of any importance exists between the two. It has also been shewn that the mammalian fauna of the lower Manchhars, although containing several species in common with the Siwaliks, is altogether older in aspect; and that the majority of the forms hitherto recognised belong to the peculiar types of even-toed ungulates allied to *Merycopotamus* and *Anthracotherium,* intermediate in character between pigs and ruminants, and peculiarly characteristic of the miocene epoch. In these lower Manchhar beds also there is found a form of *Dinotherium,* another miocene type unknown in the Siwaliks proper, though found (the species being distinct) in the beds of Perim Island. Now, there can be no reasonable doubt that the Manchhar beds of Sind, as a whole, correspond with the Siwalik formation of Northern India; for the two are portions of one continuous band of upper tertiary rocks, and, viewed in this light, the relations of the faunas are very striking, the fossiliferous lower beds of the Manchhar group corresponding to the unfossiliferous Náhans, and

forms and those now found in India, and appeared for a long time (Pal. Mem., I, p. 28) rather disposed to consider that the tertiary mammalia of India "lasted through a period corresponding to more than one of the tertiary periods of Europe" than to class the Siwalik fauna with the miocene of Europe. In his later writings he certainly spoke of the Siwalik fauna as miocene, but only incidentally; whilst in some of his latest papers he argued in favour of man having been a probable contemporary of *Colossochelys* and the Siwalik mammalia—an idea which it is difficult to reconcile with the miocene age of the fauna.

[1] See *ante*, p. 466.

the almost unfossiliferous upper Manchhar beds to the ossiferous strata of the Siwaliks. It has already been shewn how extremely difficult it is to trace particular zones amongst the confused and contorted mass of the newer tertiary deposits in the Sub-Himalayan ranges and the Punjab; but, so far as the evidence extends, it is certainly in favour of a close correspondence between the Manchhars and the Siwaliks, the upper Siwaliks being represented in Sind by the conglomerate, less fully developed there than to the northward, at the top of the series, whilst a large proportion of the lower Manchhars is made up of the grey sandstone, so well developed in the Náhan group. If, therefore, the lower Manchhars of Sind are upper miocene, so is the Náhan group of the Punjab; and it is impossible, either on stratigraphical or palæontological grounds, to class the fossiliferous middle Siwaliks lower than pliocene, the upper Siwaliks, which contain *Bos* (*Bubalus*) *palæindicus*, being probably upper pliocene. Briefly stated, the evidence is that the Siwalik fauna is newer than the Manchhar fauna, and found in higher beds, and the Manchhar fauna is not older than upper miocene.

Survival of miocene forms in Siwalik beds.—If the views expressed in the preceding paragraphs be admitted, it will be seen that we have represented in the Siwalik beds a pliocene fauna, containing an abnormally large miocene element; and although the presence of this older element may be partially due to an undetected admixture, by the collectors, of fossils from lower beds, it is certain that this explanation will not suffice to account for all the older types of Siwalik mammals; for the locality and horizon of several typically middle tertiary forms, such as *Dorcatherium*, are well known to be middle, or even upper Siwalik. An admixture of European miocene forms, though to a much smaller extent, is found in the older pliocene of North America. There is, however, a good reason for believing that European miocene forms survived to a later period in India than in Central Europe, because several genera not known in beds of later age than the miocene of Europe are found living, or are represented by nearly allied forms, in the tropics of Asia and Africa. It has even been suggested that of the two most important faunas in the tropics of the Old World, the Indo-Malayan (exclusive of that inhabiting the Indian peninsula) and the Ethiopian, the former is allied to the lower or middle miocene, the latter to the upper miocene of Europe.[1] Thus in the miocene beds of Central Europe, besides a monkey very like *Semnopithecus*, there

[1] Fraas, Württemberg'sche naturw. Jahreshefte, XXVI, 1870, p. 297; v. Pelzeln, Africa-Indien, Verh. Zool. Bot. Ges. Wien., 1875, p. 61; and Ueber die Malayische Säugethier-fauna; Festschrift, 25 Jahr. Zool. Bot. Gesellsch., 1876, p. 19; Wallace, Geographical Distribution of Animals, I, pp. 114 to 124.

are found two genera of apes, *Pliopithecus* and *Dryopithecus,* allied to the gibbons (*Hylobates*) of Assam, Burma, and the Malay countries; there is an insectivore nearly affined to *Tupaia* (Indian and Malay), and forms of deer closely resembling *Cervulus* (another Indo-Malay genus) occur, besides the living genera *Viverra, Rhinoceros,* and *Tapirus;* the two latter, however, being also found in European pliocene beds.

Pliocene fauna of Pikermi in Attica.—There is, however, one European fossil fauna which is of singular interest from its resemblance to that of the Siwalik beds. In this collection of extinct mammalia, which has been discovered at Pikermi in Attica,[1] not only is there a remarkable admixture of typically miocene forms with other species which have a later aspect, but there is the same remarkable abundance of true ruminants as in the Siwaliks. In the miocene strata, although ruminants occur, they are in general but little, if at all, superior in number to the other artiodactyle ungulates; but in the Pikermi beds there are 15 ruminants to one pig and one *Chalicotherium;* in the Siwalik fauna, 28 ruminants and but 10 other artiodactyle ungulates. Another point of similarity in the two faunas is the absence of small mammals.

The following is a list of the genera found in the beds of Greece, with the number of species belonging to each genus:—

PRIMATES—
Mesopithecus, 1.

CARNIVORA—
Simocyon, 1; Mustela, 1; Promephitis, 1; Ictitherium, 3; Hyæna, 1; Lycyæna, Hyænictis, 1; Machærodus, 1; Felis, 4.

PROBOSCIDEA—
Mastodon, 2; Dinotherium, 2.

UNGULATA PERISSODACTYLA—
Rhinoceros, 3; Acerotherium, 1; Leptodon, 1; Hipparion, 1.

UNGULATA ARTIODACTYLA—
Sus, 1; Chalicotherium, 1; Dremotherium, 2; Antilope, 3; Palæotragus, 1; Palæoryx, 2; Tragoceras, 2; Palæoreas, 1; Antidorcas, 1; Gazella, 1; Camelopardalis, 1; Helladotherium, 1.

RODENTIA—
Hystrix, 1.

EDENTATA—
Ancylotherium, 1.

Of birds, a *Phasianus,* a *Gallus,* and a *Grus* have been identified: of reptiles, bones of *Testudo* and *Varanus.* Of the above 30 genera of mammals, 13, besides *Helladotherium,* which is said to be scarcely distin-

[1] Gaudry: Animaux fossiles et geologie de l'Attique.

guishable from the female of *Sivatherinm*, are found in the Siwaliks of India : besides this, the fauna bears in many respects the same similarity to that of Africa at the present day as the Siwalik mammals bear to their living Indian representatives. Now, this Pikermi fauna is constantly quoted as upper miocene, and its connexion with the miocene beds in other parts of Europe is unmistakable, no less than 15 species being undistinguishable from those found in various miocene deposits. Several of these species are doubtfully identified, but amongst the number are such characteristic forms as *Machærodus cultridens*, *Mastodon turicensis*, and *Hipparion gracile*. But, as M. Gaudry points out in the clearest manner,[1] the ossiferous beds of Pikermi contain at their base, and below the horizon whence the bones have been obtained, a layer with pliocene marine fossils, and all the beds containing the bones, together with the pliocene marine beds, rest unconformably on lacustrine miocene rocks. There can be therefore no reasonable doubt that the Pikermi fossils, like the Siwaliks, are of pliocene age, and that the quotation of them as miocene is an error.[2]

Migration.—The points of similarity between the European miocene faunas and the animals now inhabiting either tropical Asia or Africa south of the Sahara may be due either to migration and survival[3] in a more favourable climate, or to the fauna having been formerly more uniform over large areas, and to the modified descendants continuing to live in one region, whereas they have died out and been replaced by distinct types in other parts of their old province. On the latter hypothesis we may suppose that the fauna of Central Europe and Malayasia was more or less uniform in the lower miocene period, and that Greece and Africa formed a single zoological province in pliocene days; but that the gibbon-like apes, *Tupaiadæ* and other Malay types, died out in Central Europe, and the giraffes, antelopes, &c., in Greece, whilst the descendants of their relatives survived in the Malay countries and Africa respectively. The theory of migration presents, on the whole, fewer difficulties, and is rather

[1] Tom. cit., pp. 426-435.

[2] For the theory adopted by M. Gaudry to account for the survival of these miocene animals in pliocene times, see "Animaux fossiles et geologie de l'Attique," p. 431. It appears simpler to believe that the miocene fauna of Europe migrated to the southward, and that many species survived in Greece after they had died out north of the Alps. Hence the admixture of pliocene and miocene types.

[3] It is assumed in the present and in other arguments employed in this work that similarity of organisation implies relationship of descent, *i. e.*, that animals having similar structure are descended from the same ancestors more or less remotely. The theories of evolution and of origin of species by descent with modification are now so widely accepted amongst naturalists that it is unnecessary to explain or defend them.

in accordance with the little we already know of the Indian miocene (Manchhar) fauna, in which living tropical forms appear to be less represented than they are in the deposits of that age in Europe. It is not unreasonable to suppose that some of the forms named, and especially the ruminants, migrated into Southern Asia at the close of the miocene period.

Effects of change of climate.—It is true that amongst the marine invertebrates there is a well-marked resemblance between the miocene genera of Europe and living tropical forms. The Indian and African land faunas of the early and middle tertiaries are as yet too imperfectly known for any comparison to be made between them and those of the same epoch in extra-tropical regions. It is not improbable that there may prove to have been a greater similarity than exists amongst the terrestrial forms living at present, and it is also probable that if such similarity existed, it will be found to have consisted mainly in the greater richness of the extra-tropical fauna in middle tertiary times, and in a number of types now extinct or confined to the tropics having been represented in both tropical and extra-tropical zones of climate. This last probability is founded on the fact that the temperature of Europe in the miocene epoch was in all probability nearer to that of the present tropics than to the temperate climate of recent times, and that consequently whole families of animals, and of plants intolerant of cold, then ranged to much higher latitudes than they now do. That this was the case with plants is shewn by the well-known miocene (or eocene?) flora of Greenland, Spitzbergen, and Alaska,[1] and by the species found in such marvellous abundance in the miocene beds in Central Europe.

It is by no means an improbable inference that the representation of so many European miocene genera in the Indian Siwaliks is due to changes caused by the gradual refrigeration of the earth in later tertiary times, and to the migration of the fauna towards the tropics. There is good reason for believing that Europe and South-Eastern Asia were connected by land after the eocene period; and as it is certain that a great portion of the disturbances affecting the Himalayan strata are of pliocene or post-pliocene date, it is reasonable to conclude that at the close of the miocene epoch no such mountain barrier as exists at present separated the Indian peninsula from Central Asia. There is independent evidence in favour of the view that the elevation of the Tibetan plateau is of post-Siwalik date; for remains of *Rhinoceros* and other large mammals occur

[1] Heer: Flora fossilis Arctica, Vol. III, Pt. 4, &c.

at an elevation of 15,000 feet in Tibet,[1] and it is not probable that these animals lived in so elevated a region.[2]

Comparative poverty of recent mammalian faunas.—But the immigration of the European miocene forms may not be the only way in which the Siwalik fauna was affected by the secular refrigeration of the earth's surface, culminating in the glacial epoch. It is true that there is a considerable amount of similarity between the Siwalik fauna and that of India at the present day; but, nevertheless, there is a very striking distinction—a distinction due less to change and replacement than to disappearance. Even after making allowance for the fact that the whole assemblage may not have existed contemporaneously, there is nothing so striking in the fauna of the Siwalik epoch as the wonderful wealth and variety of forms. It must be recollected that we know little or nothing of the smaller mammals, and that animals of size inferior to a pig or a sheep are scarcely represented. It would be premature to infer that, as at the present day, the more minute forms exceeded the larger types in abundance; for the conditions of intermediate ages may have affected the more bulky animals far more than the minute *Rodentia, Insectivora, Chiroptera,* &c. Still it is only reasonable to suppose that the ancestors of the present *Micro-mammalia* lived in the same profusion as they do now; and it is incredible that the living rodents and insectivores can play the parts on the modern stage and fulfil the functions of the great ungulates and carnivores of past times. Comparing like with like, and especially passing in review the *Carnivora, Proboscidea,* and *Ungulata,* all represented, and all, except the *Proboscidea,* well represented in the living fauna of India, indeed better than in most other parts of the world at the present day, it is impossible not to be struck with the comparative poverty in variety of the existing mammalian types. We have of course but an

[1] There is, on the other hand, a probability that the elevation of the great plateau of Central Asia dates from a period prior to the glacial epoch, or at least antecedent to the close of the cold period, because, in the first place, there are numerous signs of ice having formerly occupied a much greater area than it does at present; and secondly, there is a very remarkable change in several species of migratory birds between the forms found in Western India (many of which are common to Europe) and those found in Eastern India and Burma, many of which are peculiar to Eastern Asia. The two groups meet in India; and although stragglers are found to the east and west of the limit, they are not common. The contrast is easily explained if the breeding places of the representative races have been separated for ages through the elevated regions of Central Asia being so covered by snow and ice as to be unfitted for birds, and especially for insectivorous birds, to breed in. Amongst examples of the representative races, *Motacilla alba* (v. *dukhunensis*) and *Erythrosterna parva* of Western India, replaced by *M. luzoniensis* and *E. albicilla* to the eastward, may be quoted.

[2] Falconer, Pal. Mem., I., p. 173.

imperfect knowledge even of the larger Siwalik animals, and remains of *Carnivora* are rare, so much so that probably many species remain undiscovered; but even at present the known Siwalik carnivores are more numerous than the living forms of similar size in the same area, and the ungulates exceeded their living representatives in number in the proportion of more than 5 to 2, there being 50 known Siwalik species and only 18 recent. The superior wealth of the older fauna is both generic and specific; not only are the types more varied, but there is a greater variety of forms in many of the genera; thus 6 species of *Rhinoceros* existed where now there is only 1, or, including Eastern India and Burma, only 3; and no less than 11 extinct elephants and mastodons are represented by a solitary living form. Even such modern types as *Bos* have dwindled in numbers from 6 to 2.

This great impoverishment of the recent mammalian fauna is not peculiar to India. It is found in other parts of the Old World and in America, wherever remains of animals have been preserved in sufficient quantities amongst the deposits of the later tertiary epochs for a good idea of the fauna to be presented. In the words of Mr. Wallace, "we live in a zoologically impoverished world, from which all the largest and fiercest and strangest forms have recently disappeared;" and he makes the happy suggestion,[1] that this enormous reduction in the numbers of the greater mammals is due to the glacial epoch. Thus for a second time we find the action of this great physical change reflected in the Siwalik fauna; and we have an addition to the arguments urged in the sixteenth chapter[2] in favour of India having been affected by the cold period which immediately preceded the present day.

The post-pliocene Narbada fauna is very poor compared with the Siwalik. It is true that the former comprises two species of elephants and two of hippopotamus; but only two bovines have been detected, one deer, and one antelope. This difference may be partly due to imperfect knowledge, to the much smaller range, both in area, and in time as represented by thickness, in the case of the Narbada beds; but none of these circumstances can possibly account for the whole distinction; for large collections of Narbada bones have been made, and more ruminants would surely have been detected, had many existed. It is probable that the Narbada fauna is posterior in date to the main operation of the agency, whatever it may have been, that caused so many of the Siwalik mammals to die out. The further diminution in the numbers of *Proboscidea*, and the complete disappearance of the genera *Hippopotamus* and *Rhinoceros* from Central

[1] Geographical Distribution of Animals, I, p. 150.

[2] *Ante*, p. 372.

India, may perhaps have been partly due to the agency of man, who, if the evidence of the chipped quartzite implement already mentioned [1] can be trusted, must have been a contemporary of the Narbada fauna.

Relations of Siwalik to Perim Island fauna.—Before quitting the subject of the relations between the Siwalik and other fossil faunas, two other Indian deposits containing mammalian remains require notice, besides the miocene beds of Sind and the Punjab, and the post-pliocene formations of the Ganges valley and the Indian peninsula. These two deposits are those of Perim Island in the Gulf of Cambay, the known species from which locality have already been quoted [2] and are marked P in the preceding list of tertiary fossil vertebrates, and those of the Irawadi valley in Upper Burma marked I.

The known mammals from Perim Island comprise ten species, of which four, viz., *Mastodon latidens, M. perimensis, Acerotherium perimense*, and *Sus hysudricus*, are common to the Siwalik beds. All these forms are, however, found in other fossil faunas; *Mastodon perimensis* and *Sus hysudricus* being met with also in the lower Manchhar beds of Sind, *Acerotherium perimense* in the Irawadi deposits, and *Mastodon latidens* in both, so that all the forms common to Perim Island and the Siwaliks are clearly species of wide range. The absence of *Elephas* and its sub-genera, and of bovines, and the presence of *Dinotherium*, tend strongly to make the Perim Island fauna appear of greater age than the Siwalik generally; but, on the other hand, the presence of so highly specialised a genus as *Capra*, if the generic determination be accepted,[3] the occurrence of *Camelopardalis* and *Antilope*, and, above all, the absence, so far as is known, of any of the *Anthracotheridæ* and other older ungulate types so abundant in the miocene beds of Sind and the Punjab, are opposed to the idea that the Perim Island rocks can be of higher antiquity than pliocene. They possibly occupy an intermediate position between the Siwaliks proper and the Manchhars of Sind, but they are more nearly allied to the former.

Comparison with Irawadi fauna.—It will be necessary to revert to the mammalian remains found in the Irawadi valley when describing the rocks of Burma. All that it is now necessary to point out is that, although the proportion of species identified with Siwalik forms is rather less than in the case of Perim Island, only four species, viz., *Stegodon cliftii, Mastodon latidens, Acerotherium perimense*, and *Merycopotamus*

[1] *Ante*, p. 386.

[2] *Ante*, p. 343.

[3] It should not be forgotten that *Capra perimensis* is founded solely on a frontlet with the horn-cases, and that nothing is known of the greater part of the cranium, the teeth, or the limb bones. See Lydekker, Pal. Ind., Ser. X, 3, p. 83-170, Pl. xxviii, fig. 4.

dissimilis, out of thirteen, being known to be common to the Siwaliks and the Irawadi beds, the general facies of the two faunas is very similar. Both contain a considerable proportion of living genera unknown in the middle tertiaries of Europe, together with some older forms, such as *Acerotherium* and *Merycopotamus*. The Irawadi fauna perhaps may be equivalent to upper Siwalik.

The Tibetan mammalian fauna[1] already noticed is too imperfect for comparison.

Comparison of Siwalik and recent faunas.—Lastly, a few words may be added as to the points of connexion between the Siwalik fauna and that now found in India, Malayasia, and Africa. The most remarkable distinction between the mammalian life of tertiary times and that of the present day, the comparative wealth of the former and poverty of the latter, has already been noticed; but it is matter of some interest to trace how far the Siwalik types are represented by animals now inhabiting India, and how many of the tertiary genera, though still living on the earth's surface, are no longer found in the regions formerly inhabited by their Siwalik allies. As the fauna of India varies in different parts, it will be best to take for comparison with the Siwalik mammals all forms now existing in the Indo-Gangetic plain, from the Indus to the parallel of Calcutta, together with those inhabiting the lower slopes of the Himalayas up to 4,000 or 5,000 feet. This area comprises portions of three distinct zoological sub-provinces, the animals inhabiting the Indo-Gangetic plain to the westward exhibiting some distinctions of importance from those occurring to the eastward, and the lower slopes of the Himalayas having a very different fauna, distinguished by the presence of numerous Malay types. In this comparison, again, the minor generic or sub-generic groups of many modern naturalists are not enumerated; *Rucervus, Rusa,* and *Axis,* for instance, being considered merely forms of *Cervus,* and *Bibos, Bubalus,* &c., of *Bos*. The following is a list of the Siwalik genera represented by species living in Northern India,[2] the number of such species being added:—

PRIMATES—

Semnopithecus, 2; *Macacus, 1* (or 2).

CARNIVORA—

Felis, 8[3]; *Hyæna, 1*; *Canis,* (including *Vulpes*), *4*; *Ursus, 1*; *Mellivora, 1*; *Lutra, 2* (or 3).

[1] Falconer, Pal. Ind., I, p. 173; Strachey, Q. J. G. S., 1851, p. 292.

[2] The living genera are taken chiefly from Jerdon's Mammals of India, a few alterations and additions being made.

[3] Five of these are of small size.

PROBOSCIDEA—
Elephas, 1.

UNGULATA PERISSODACTYLA—
Rhinoceros, 2 (both only found to the eastward, and the second species barely within the area) ; *Equus, 1* (also barely within the area, but to the westward).

UNGULATA ARTIODACTYLA—
Sus (including *Porculia*), *2* (or 3) ; *Cervus, 4* ; *Antilope* (including *Gazella*), *2* ; *Bos, 2* ; *Ovis, 1* (in the Punjab only). *Capra* is not found living in the area named, but 3 species exist on the higher Himalayas, and two on the hill ranges to the west of the Punjab.

RODENTIA—
Mus, many species ; *Rhizomys, 1* (only found to eastward) ; *Hystrix, 2* (or 3).

The genera of *Ungulata* now found in Northern India and not represented, so far as is known, in the Siwalik fauna are only four : *Cervulus, Portax, Tetracerus*, and *Nemorhedus*. Some twelve genera of living Indian and Himalayan *Carnivora* have not been found in the Siwalik rocks, but all are of comparatively small size ; *Viverra, Arctictis, Cuon*, and *Paradoxurus* being the largest.

The Siwalik genera not now living in Northern India, but still existing elsewhere, are *Meles* and *Camelus*, now confined in the wild state to the palæarctic region, and *Hippopotamus* and *Camelopardalis*, both surviving in Africa. All the other living forms already enumerated are common to India and Africa south of the Sahara, except *Semnopithecus, Macacus, Ursus, Cervus, Ovis*, and *Rhizomys*, whilst *Hyæna, Canis, Mellivora, Equus, Antilope*, and *Ovis* are unknown in the Malay regions. The genera common to the Siwalik fauna and Malayasia, but not found in Africa, are *Semnopithecus, Macacus, Ursus, Cervus*, and *Rhizomys*. The first two and the last of these are, however, represented by allied forms in Africa, whilst no such near Malayan representatives of any of the Siwalik-African forms, except *Canis* (replaced by *Cuon*), can be mentioned. It may be added that of the twelve genera of living Indian *Carnivora* unrepresented in the Siwaliks, the majority are Malayan forms inhabiting the Himalayas. It is clear that the Siwalik fauna resembles that now inhabiting Southern Africa more than it does the assemblage of living *Mammalia* now found in Malayasia, and it is probable that this resemblance is due to both the pliocene Siwaliks and the recent Ethiopian faunas, together with a very large proportion of the animals now inhabiting the plains of India, being descended partly or wholly from the same ancestors, and perhaps from their ancestors having originally migrated southward from the miocene lands of Central Europe and Asia. We know nothing of the miocene mammals of Southern Africa, but such information as we possess of the

upper miocene fauna of Northern India renders it probable that most of the Siwalik mammals emigrated about the close of the miocene epoch, and a portion of the descendants of the Siwalik immigrants may have inhabited the country ever since. Many forms have, however, died out, and it is probable that in comparatively recent times some of these extinct forms have been replaced by Malayan types, either introduced from the eastward, or spreading northward from the singularly isolated Malayan faunas now inhabiting the Malabar coast and the Southern Indian hills. Many, however, of the forms which at first sight appear to have distinctly Malayan affinities, such as *Cervus* (*Rucervus*) *duvaucelli* and *Bos gaurus*, despite their close alliance with living Malay forms, and the want of related species in Africa, are probably descended from Siwalik ancestors, and are not Malayan immigrants. Again, in a few cases, as in that of the Indian gazelle, some of the species which, judging by their range and their close connexion with forms inhabiting other countries, are amongst the most recent additions to the Indian fauna, come from the west and not from the eastward.

CHAPTER XXV.

EXTRA-PENINSULAR AREA.

LOWER HIMALAYAS.

Limits — General features — The terminal area — Classification of rocks — Correlation of groups — The gneissic series — The slate series — The Simla slates — The Blaini group — The Infra-Król — The Król group — The relation of the slate and gneissic series. Special metamorphism and disturbance — Trappean rocks — The Chor mountain — South-east of Simla. Kumaun and Gharwál. Nepál. The Sikkim area — Darjiling gneiss — The Dáling series — The Damúda series — Relations of the three series — The Bhútán border: Baxa series — The Dikráng section. SUMMARY.

Limits.—The name "Lower Himalaya" does not spontaneously suggest the area to which it is here restricted. This is not a mountain-zone of medium elevation, continuous between the Sub-Himalayas and the Central or Tibetan region; for, as already stated (p. 557), we find the tertiary rocks in the Kángra district within a mile of a lofty ridge of "central gneiss," on the prolongation of the main Himalayan axis, and structurally belonging to the Tibetan region. Still, to any one who knows the ground, the character "Lower" would suggest the area in question; for the ridges of the Dhauladhár and Pir Panjál, belonging to the Central Himalayas, and overhanging the Sub-Himalayan zone in the north-west, are much more lofty, rugged, and persistent than the mountains of the Lower Himalayas, occupying the broad area, some 50 miles wide, between the great snowy range and the plains.

To the east this feature continues beyond the range of exploration, in the mountains north of Assam: on the west it ends, or begins, abruptly very nearly on meridian 77° E., a short distance west of Simla. Both the Biás and the Sutlej flow from east to west across this terminal boundary of the Lower Himalayan region, while the Tons and the Jumna are the first rivers having a southerly course in this ground. The mention of these rivers shews that the meridional watershed of India occurs here; but this is a fact of no significance; for it is possible that almost within historical times the Jumna may have flowed westward, instead of to the Ganges.[1] Simla stands on the Sutlej-Jumna watershed, and, as

[1] See page 417.

a well-known place, its name has been given (p. 529) to this terminal region of the Lower Himalayas. If a politico-geographical name were required for the Lower Himalayan region, the kingdom of Nepál would furnish the most suitable, as it occupies the whole middle area for a length of 500 miles; and the Gurkhas of Nepál formerly held sway to beyond the Sutlej.

General features.—The character chosen to designate this region of the mountains is a superficial one; yet it is an index of important structural peculiarities: the low general average of elevation is due to the irregularity of the disturbance that has affected the rocks, without producing any dominant lines of dislocation or of upheaval; being thus in marked contrast with two other divisions of the mountains, where steady outcrops are determined by continuous parallel axes of flexure and of dislocation. There is, no doubt, a very decided prevalence of a strike parallel to the general mountain-axis, and the dominant dip of the strata is towards that axis; but local interruptions are so frequent, that the general result, as brought out by the drainage courses, is more like that from the denudation of a homogeneous mass. It has been suggested[1] that the present rivers cross this area on lines of fracture; but observation lends no support to the opinion: the drainage channels, great and small, are as devious as they could be worn through a promiscuous mass of broken materials. A possible cause for this condition will be suggested.

The boundaries of the Lower Himalayas are, however, well defined. On the north, so far as known from the west end, there is the great gneissic axis, with constant granitic intrusion, forming the main snowy range. On the Sub-Himalayan border, along the "main boundary" of the tertiary zone, there is also, from the west up to Nepál, some approach to constancy in the older rocks. They are intensely contorted, but with more steadiness of direction than in the interior of the area; although still there are numerous breaches of regularity, as at the sharp bends of the main boundary east of Dehra, and again just east of the Ganges, both of which coincide with twists in the strike of the slates. This circumstance (the local strike of the strata at these points) is perhaps an additional argument in favour of this boundary being primarily a feature of denudation, or at least against its being a great master-dislocation (p. 540).

Regarding the distribution and structure of the rocks in the Lower Himalayas, our information is still more scanty than in the case of the Sub-Himalayas, and our description must be correspondingly bare. For a

[1] Q. J. G. S., VII, p. 309.

length of 500 miles in Nepál, we have only notes upon one short section in the middle; and to the east of this, throughout the whole range, only one narrow area has been examined, in Sikkim. It is in the north-western portion that most observations have been made, and it is there that the rocks are in the most favourable condition for study, as exhibiting least metamorphism. This is apparently due to the position being a subterminal one in the mountain area. However this may be, we find here a continuous broad belt of unaltered limestones and shaly slates at the edge of the mountains; and at many points they extend far into the interior. This border contracts gradually to the eastwards, being comparatively narrow, though still well marked, at Naini Tál; but on the Kathmándu section it has disappeared, and in Sikkim gneissic rocks come very close to the southern or main boundary. The relation of these unaltered rocks to the gneissic series is the chief puzzle of the Lower Himalayas. The boundary of the two is as irregular as it can be, and quite unlike any feature described in other Himalayan regions.

As in the case of the Sub-Himalayas, and for analogous reasons, we must describe the Lower Himalayas in sections of areas, commencing at the west end, with the terminal area already denoted as the Simla region.[1]

The terminal area.—It is important to note at starting that the termination of the Lower Himalayas, in about 77° of east longitude, is strictly a feature of the general mountain-structure, the boundary there being more or less homologous with that elsewhere. The several rock-series of the area do not continue with their general north-westerly strike up to the terminal boundary, nor end there along a transversely denuded outcrop, against the tertiary formations. Here, as elsewhere, the strike of the old rocks conforms to the main boundary, even when almost at right angles to the axis of the range; and the same external band of unaltered palæozoic rocks intervenes continuously between the gneiss of the interior and the fringing tertiary formations. This condition holds good for the whole Western Himalayas, the strata forming throughout an independent system of disturbance: at no point along the mountain border on this side do the gneissic rocks touch the Sub-Himalayan zone, so they can never (in, or since, silurian times) have been continuous with the crystalline rocks of peninsular India. This fact would be almost a corollary from the statement already given (p. 569), that the contortion of the slates is of post-nummulitic date; it may now be quoted as a confirmation of that statement.

[1] For some particulars of this ground, see Mem. G. S. I., III, Pt. 2, 1864; and Rec. G. S. I., X, p. 202, 1877.

Classification of rocks.—The following petrographical groups are distinguishable in the Simla Himalayas. It is convenient to consider them as two series, although they may be in part equivalent; the relation between the two being the great puzzle of the geology of this region, and the chief contrast between it and the Central Himalayas.

A—Outer, newer, or slate series—	
Król: limestones, sandstones and shales	800—1,200
Infra-Król: shales (often carbonaceous) and flags	1,000—3,000
Blaini[1]: limestone, sandstone and conglomerate	100
Infra-Blaini (Simla slates): slates and flags	over 5,000
Base not known.	
B—Inner, older, or gneissic series—	
Gneissose schists	6,000
Massive gneiss	100—600
Schistose gneiss	?

Correlation of groups.—The absence of fossils is one of the most puzzling facts connected with the geology of this area, and the same remark applies to these formations throughout their extension on the southern face of the Himalayas, eastwards to Nepál and westwards to the Jhelum. All the rocks of series A are such as might be expected to contain organic remains; they are fully exposed to view at some much frequented localities, as in the hill stations of Mansúri (Mussooree) and Naini Tál, and on the road to Simla,—at all of which many skilled observers have searched carefully for fossils, but in vain. Only one authentic case of organic remains from these rocks is on record:[2] some indeterminable casts of bivalve mollusks from a band of limestone in the Tál, or Bheng, river, at the end of the Dehra Dun, east of the Ganges.

In the absence of fossils, an attempt at identification can only be made through comparison with sections of known rocks, or by continuous connexion with known sections. On the former grounds, the following conjectural affiliation was made by Dr. Stoliczka, through a comparison with the rocks described by him in Spiti, beyond the snowy range due north of Simla.[3]

Simla.	*Spiti.*	*Europe.*
Król limestone.	Liláng series.	Upper trias.
Infra-Król.	——	Lower trias.
Quartzites and mica-schists at Simla.	Kuling.	Carboniferous.
Blaini.	Muth.	Upper silurian.
Infra-Blaini (Simla slates).	Upper Bhábeh.	Lower silurian.

[1] Formerly spelt "Blini": the first vowel sound is full, as in blind, so the correct spelling is "Blaini."

[2] Mem. G. S. I., III, Pt. 2, p. 69.

[3] Mem. G. S. I., V, p. 141.

On the same page (*l. c.*) Dr. Stoliczka mentions a prior recognition of the infra-Król beds as lower trias, from their being mineralogically so very similar to the Bunter Sandstein of Europe; and no remark is so frequently repeated in Stoliczka's later Himalayan notes as the resemblance of the semi-oolitic triassic limestone to the Król rock. An apparent confirmation of the age assigned by Dr. Stoliczka to the Król group was published about the same time[1] in Professor Gümbel's description of a specimen, from the Schlagintweit collection, said to have been obtained at Dharampur near Solan in the Simla district, containing three fossils, *Lima lineata* and *Natica gaillardoti*, found also in the Muschelkalk in Europe, and a new species, *Nat. simlaensis* (Gümb). In view of all the circumstances,[2] however, it seems safest to doubt the authenticity of this specimen. The well-known locality Dharampur, in the neighbourhood indicated, is certainly on nummulitic rocks, and there can be but little doubt that the specimen in question came from some totally different ground, possibly from Tibet.

The method of connected observations has suggested a different correlation of the upper members of the Simla series. These rocks, as has been said, are continuous, although locally much contracted and obscured, along the Himalayan border up to the Pir Panjál, and the limestone there occurring, like that of the Simla region, at the top of the slate series, has been satisfactorily identified by Mr. Lydekker[3] with the carboniferous limestone of Kashmir (the Kuling limestone of Tibet), and quite distinct from the triassic limestone, which also occurs in the valley. He also thinks that the infra-Król is carboniferous, leaving the Blaini group and the Simla slates to represent the Muth and Bhábeh rocks of Tibet, as silurian. In the Pir Panjál and Kashmir, as in the Lower Himalayas, these lower rocks have as yet proved unfossiliferous; but there can scarcely be a doubt of their representing the infra-carboniferous slates of Tibet in which silurian fossils have been found.

The gneissic series.—The gneissic and schistose rocks, even in the Simla region, occupy the largest portion of the Lower Himalayan area south of the great snowy range. That range, westwards from Nepál, has been described by different observers as formed of, or supported by, gneiss, with extensive intrusion of granite. In describing this gneiss between the Sutlej at Wangtu and the Bhábeh pass, north-east of Simla, Dr.

[1] Sitzungsber. bair. Akad. d. Wiss., 1865, II, p. 354.

[2] So many serious errors have been found to exist in the localities assigned by the Messrs. Schlagintweit to their reptilian and other collections, that no dependence can be placed upon any specimen collected by them.

[3] Rec. G. S. I., XI, p. 63, 1878.

Stoliczka distinguished it as the "central gneiss," asserting that, geologically speaking, it had nothing to do with the gneiss of the Lower Himalayas to the south of it.[1] It is presumable that there was some better ground for this opinion than the presence of an eruptive rock in the gneiss along this mountain axis; but however this may be, it has been shewn beyond reasonable doubt by Colonel McMahon[2] that the crystalline series forming the peaks south of Wangtu, of which the Simla watershed is an offshoot, is the same as that of the main range.[3] The massive granitoid gneiss which, although subordinate, is the most conspicuous member of the series, and thus was unfortunately made its representative member, passes into the north base of these southern peaks above Sangla on the Baspa (which joins the Sutlej south of Chinî), at an elevation of about 10,000 feet; and it emerges on the south base at Lorot (20 miles due south-west from Sangla) at the head of the Pabar valley, at an elevation of about 8,500. In the intervening mountains of Bisáhir, crossed by the Borendo and Rupin passes, the stratification lies flatly, and there must be some 6,000 feet of the gneissose schists overlying the more granitoid rock. Although no granite has been observed here, these are no doubt the same as the schistose gneiss, having a high northerly dip, described by Dr. Stoliczka in the Bhábeh section (*l. c.*, p. 14) and distinctly included by him in his "central gneiss." The opinion that this gneiss was restricted to the main mountain axis was, no doubt, a principal reason for the name given to it, which is certainly not altogether appropriate to the real state of the case. "Lower gneiss" would have been a better designation for it, as it is probably the oldest rock in the whole Himalayas. In the Tibetan region we shall find gneiss that is probably an altered silurian rock; whereas the junction of the Lower Himalayan gneiss with the silurian slates on the north side of the main range is represented as abrupt, if not unconformable; although the granite is said to penetrate even up to the overlying secondary rocks.[4]

This determination of the Lower Himalayan gneiss in the Simla region to be the same as that of the main range, is a point of great importance; as it at once disposes of the conjectures that had been hazarded, as to its being possibly of later age than the Król rocks; and it is only fair to suggest that those conjectures may have influenced

[1] Mem. G. S. I., V, p. 15.

[2] Rec. G. S. I., X, pp. 216—221.

[3] It should be recollected that Dr. Stoliczka did not himself survey the Simla region, and that his examination of the gneiss in this part of the Himalayas can only have been of the most cursory description.

[4] *l. c.*, p. 12.

Dr. Stoliczka's decision upon the distinctness of the two gneisses. Supposing the massive band of granitoid gneiss to have an approximately fixed position in the series, as is implied for this area by the foregoing observations, it will be of great service in tracing the position of the gneissic series and its relation to the slate series. On the secondary ridge, and principal watershed, running west-south-west from the Bisáhir peaks to Simla, this gneiss forms the crest at Hatu (10,469); and it is very prominent below the crest in the southern branch, forming the Shankan ridge, from which it passes eastwards into the valley of the Pabar. A low east-north-easterly dip is the general lie of the gneiss in this position. Hatu would seem to be on the crest of an anticlinal, and 8 miles to the north, in the Sutlej (3,000), the same gneiss, or what we are supposing to be the same, forms the banks of the river from Kamársen bridge, nearly to Rámpur, the capital of the Bisáhir State. North of the Sutlej, in the Jalori ridge, running from the snowy peaks of Kulu west-south-westwards to the Cheru summit (10,134), within 12 miles of the tertiary zone, a massive granitoid gneiss again occurs, with a prevailing low easterly dip.

All these gneissic rocks of the interior are continuous with the crystalline mass of the main chain; and the principal feature to notice about them is their small disturbance as compared with their state in that chain, or with the condition of the newer rocks forming the outer zone of the Lower Himalayas. But there is one mass of granitoid gneiss differently circumstanced in the Simla area, forming the Chor mountain (11 982 feet high), 25 miles south-east of Simla, and 20 miles from the main boundary at Náhan. Lithologically, the rock forming the Chor is the same as the massive gneiss of Hatu and elsewhere, but in the first-named mountain it is quite surrounded by the rocks of the upper series. It will be described further on.

The slate series.—Although true slaty cleavage, distinct from lamination and jointing, is of rare occurrence in the Lower Himalayas,[1] the prevailing type of rock in the newer series, indicated on p. 595, is that best described as slaty; and it will be convenient to speak of these rocks collectively as the slate series, as distinguished from the lower metamorphic series. Locally, the texture is below this standard of induration, and the rock is rather shaly than slaty, as in the Infra-Król shales at the base of the Król mountain. Locally also, and more frequently, crystalline foliation is well developed, where the rock is rather schistose than slaty; as in those same Infra-Król shales on Jako at Simla.

[1] Mem. G. S. I., III, Pt. 2, p. 72.

The normal order of this series is nowhere so surely displayed, with so little disturbance and alteration of the strata, as in the Simla region, just inside the Sirmúr rocks of the standard area, on the main road to Simla. From the Solan rest-house the Król mountain (7,406) on the north, the Bój on the west, and Kanój on the south-east, are within easy walking distance. They are formed, above the road level, of massive limestone, more or less isolated upon a base of earthy slates, thus leaving no doubt that the limestone is the latest of the series. The Blaini stream rises just west of Solan; and in its channel the small, but highly distinctive, group that bears its name is repeatedly exposed, sometimes in contact with the nummulitic clays. Considering its persistent small dimensions, this Blaini group has a remarkably wide distribution, having been traced in typical form as far as the Król limestone itself; and thus a much-needed horizon can be recognised in an immense thickness of rocks that could scarcely otherwise be separated, and a clue is furnished whereby to unravel and delineate the very complicated disturbance to which these outer rocks have been subjected.

So far as can be, or at least has been, made out in the outer zone of the mountains, there is conformity between the several groups of the upper series; but in discussing the relations of the two series, facts will be observed involving the overlap of the upper groups at or about the Blaini horizon.

The Infra-Blaini rocks (Simla slates).—In the neighbourhood of Solan, where the three upper groups of the slate series are typically seen, the Blaini rocks occur in the lowest ground, so the underlying formations are not exposed. These may be well seen near Simla, below the Blaini outcrop on the east in the valley of the Ussan, and on the north towards the Sutlej. They consist of finely laminated slaty shales and thin sandy flagstones, with occasional beds of earthy sandstones. The lamination is sometimes fine enough and the induration sufficient to produce serviceable roofing slate, but much inferior to true cleavage slates. From the Blaini rocks at the Lakri Bazaar there is an apparently unbroken succession of the Simla slates to Náldera (the ridge above Bassantpur), where the limestone of the Sutlej valley begins; the dip is steady, and there is no trace of a flexure; 5,000 feet is a low estimate of the thickness of such a section. The limestone just mentioned is supposed to be the Król limestone, brought down by faulting; and, as in every other known section, the actual substratum of the Simla slates has not been observed in this region.

The Blaini group.—This group consists of two very distinct members, each of which seldom exceeds 50 feet in thickness, and is generally much less. The upper rock is a fine, compact or micro-crystalline

magnesian limestone,[1] of pale-grey and pink tints, thin bedded, but often amalgamated into a single mass. It rests upon a quartzite sandstone, often a clear quartzose rock, but sometimes rusty and more or less earthy. In whole or in part this lower band is very often highly conglomeratic, with well-rounded pebbles and small boulders of white quartz and variously-tinted quartzites, and sometimes partially-rounded debris of slate rocks. Pebbles of crystalline rocks have not been observed in it in this region. Although often crushed together, mixed and inverted, these two rocks seem never to have been interstratified originally; and it is possible, notwithstanding their so constant association, that they were considerably separated in age. The persistent occurrence of two thin bands of such different types of rocks over so large an area is a remarkable circumstance, but a most fortunate one for the geologist who undertakes the study of this difficult ground.

Infra-Krol group.—This is a provisional form of nomenclature, and it is not improbable that "lower Król" group would be more appropriate; but until the connexion can be based upon palæontological facts or more extended observation of the strata, it is safer to adhere to the more vague expression of the relation. At the base of the Król, north of Solan, the soft black infra-Król shales are very well exposed. The carbonaceous element is the most striking character of the group, but it cannot be adopted as an essential one, or even perhaps general. Sometimes this character extends down to the beds overlying the Blaini limestone, as in the outcrops on the Ghambar between Kiari Ghát and Sairi; but often it is wanting in beds that seem to belong to this horizon, as along the Solan watershed, on the crushed anticlinal between the Król and the Bój. In the absence of faulting, or of an outcrop of the Blaini limestone here, all the beds should belong to the infra-Król group, but they are not carbonaceous. It may perhaps be questioned whether this can be attributed to a subsequent removal of the carbonaceous ingredient, or to an original inequality of distribution. This carbonaceous ingredient of the shales is, however, very widely spread, being well seen at Mansúri (Mussooree), and other places at a distance from the Simla region. The shiny black crushed rock, so common in faulted ground in this region, is presumably derived from the carbonaceous beds of the infra-Król group.[2]

[1] McMahon: Rec. G. S. I., X, p. 210.

[2] *Subathu Coal.*—The coaly aspect of this carbonaceous shale, especially where made glossy in crushed ground, has often raised expectations of finding coal. In 1862, Colonel Fyers, in spite of warnings, made an attempt at mining upon an outcrop of this crushed rock near Subáthu, expecting to find coal to the deep. The stuff contains sometimes as much as 25 per cent. of fixed carbon, besides 11 per cent. of volatile matter, partly hydrocarbons.

In the neighbourhood of the Król or at Simla, a thickness of about 1,000 feet would include the beds between the Blaini limestone and the base of the Król group; elsewhere there is a much greater apparent thickness, as from the base of the Tára Devi quartzite at Mán Ghát summit, to the outcrop of the Blaini group in the Ussan, where the thickness would seem to be 3,000 feet. But in all these sections the strata are greatly affected by small slips; and these interfere with any attempt to estimate the dimensions of the groups, and tend either to exaggerate, or to diminish the true thickness.[1]

The Krol group.—On the Król mountain, from which it takes its name, the top group consists almost entirely of limestone, a pale-grey compact or crypto-crystalline rock, sometimes dark and locally oolitic; but even here there are subordinate shaly beds, sometimes pale pink, and at the base there is a variable band of clear coarsish quartz sandstones. The calcareous element is decidedly the prevailing character of the group, as compared with the underlying slate series, which is remarkably deficient in this ingredient. The sandy element, however, is often very prominent. As an expansion of the bottom band, this fact is well exemplified at Simla, in the massive quartzites of Boileauganj, and of Tára Devi ridge to the south, overlaid by a remnant of the Król limestone at Jutog. Elsewhere, as south of Guma peak in Sirmúr, the limestone itself is rather a calcareous sandstone, or occurs as subordinate bands in a mass of sandstone. When the ground comes to be worked out, these variations will be useful, as suggesting local conditions of deposition; and the establishment of this character in the standard area will facilitate conjectural identification of the group elsewhere, as in Nepál.

The relations of the slate and gneissic series.—No special account has been given of the distribution of each group, nor of the structural features of the ground, because the little that is known of either will be fully exhibited in discussing the difficult question of the relation of the two rock-series. The structural peculiarities of the Lower Himalayas are best shewn by contrast with those of the other regions of the mountains. All the boundaries hitherto noticed were determined along what are clearly Himalayan lines of disturbance. Even in the middle region, where both the bottom tertiary and middle tertiary junctions were shewn with some probability to be aboriginal, *i. e.*, primarily (as junctions) lines of deposition, these had previously been determined as lines of erosion by the early results of Himalayan disturbance. In the North-West, again, where the Sub-Himalayan and Central Himalayan features come together, there is complete correspondence between the structural features in the

[1] Mem. G. S. I., III, Pt. 2, p. 37.

gneissic axes of the Dhauladhár (the range just north of the Kángra valley) and the Pir Panjál (the range south of Kashmir), which are constructed on the same pattern as the latest ridge of the Siwaliks. The change is immediate where, at the east end of the Dhauladhár, the Lower Himalayan region begins : the boundary of the slate and the gneissic series here does not run even approximately parallel to the main boundary ; it bends east and then north, round the point of a ridge of gneiss, up the valley of the Biás towards Sultánpur, and thus all round the basin of the river and its tributaries to the south, where it runs to south of west along the Jalori ridge of gneiss, separating the Biás from the Sutlej, and then round the point of this ridge and along its south flank to far up the valley of the Sutlej.

Other changes are commensurate with this remarkable one in the outline of the boundary : from being a single narrow outcrop along the base of the Dhauladhár, the slate and limestone series spreads into a wide area (some 20 miles by 30) in the Biás basin, and similarly on the Sutlej. The structural features in the two positions are equally discrepant : along the Dhauladhár the strata are vertical, or underlie towards the gneissic axis in *inverted order ;* whereas in the great river basins of this terminal area of the Lower Himalayas, the confused contortion of the rocks within the basin is beyond description ; but at the boundary the dip on all sides is towards the overhanging ridge of gneiss, and in *normal order,* the great or Król limestone being uppermost.[1]

The appearance is as if the slate and limestone series really passed beneath the gneiss, and were older than it ; but if this gneiss is the same as that of the main range, such a view would be untenable. The supposition which would best represent the facts to the imagination is, that these deep and precipitous valleys in the gneiss had existed in pre-silurian, or at least pre-carboniferous times, and had become filled with deposits of those periods. Under subsequent compression the disturbance would principally take effect upon the softer later deposits, and in a manner corresponding with the features described. It is doubtful indeed whether any other supposition will fit the case : the structural features may almost be said to be incompatible with the view of their formation by faulting or inversion, produced by lateral thrust upon any parallel sequence of strata, the very different results of which processes are so well illustrated in neighbouring areas.

An apparently complete refutation of the objection just stated, against the explanation by faulting, is found in the Sutlej basin. The Sháli mountain (9,420′), which forms such a picturesque object in the land-

[1] Mem. G. S. I., III, Pt. 2, p. 50.

scape from Simla, is formed of limestone, and it stands within the special basin of disturbance in question. Above and east of the gap connecting the Sháli with the watershed-ridge east of the Sutlej, there is an outcrop of the Blaini group, dipping north-eastward; and from the Sháli the limestone passes to the south-east, and round the head of the valley under Thiog, Fágu, and Mahásu, into the Náldera ridge, where, we have already seen (p. 599), it apparently passes southwards under the base of the Simla slates. Thus on the south side the rocks of the Sutlej valley behave towards the slate series of the typical area, as they do to the gneiss on the north side; and it would seem that the crucial evidence, whereby to judge the whole case of these valleys full of the latest beds of the series, were to be found here, where the horizons of the contiguous rocks are more comparable.

The question turns upon the point, whether the limestone of the Sháli, and of the Sutlej and Biás valleys, is the same as the Król rock; and, so far as our observations go, the answer is in the affirmative. The general resemblance of the two rocks is sufficiently marked, and the differences are no greater than have been observed in the Król rock within its standard area. Carbonaceous beds also are found in both of those valleys; and in one case an outcrop of the Blaini group has been marked, north of the Sutlej, on the spur north-west of Bihul; where, in contact with a broad dyke of trap, there is a small thickness of coarse quartz conglomerate, overlaid by slate and thin-bedded limestone.[1]

Accepting this identification, we are then bound to suppose a dislocation and downthrow of great magnitude in the Sutlej valley, or an upheaval of the ground at Simla and to the west of it. The Blaini outcrop north of Simla passes westwards along the flank of the ridge to Dhamini, where it turns south and then south-east, following a devious course to near Haripur on the old road to Simla.[2] Thus the form of this inevitable dislocation is quite on a par with that of the boundary with the gneiss between the Sutlej and the Biás. We cannot, however, reasonably apply this crucial evidence all round, without consideration of the objections already noted. We have seen how regularly even the oldest rocks can conform to the lines of Himalayan disturbance—a fact which implies some approach to original homogeneity of disposition in the strata so affected; and, in like manner, it seems obligatory to account for such very abnormal lines of dislocation as that under notice by supposing a

[1] Mem. G. S. I., III, Pt. 2, p. 56.

[2] For the observations here quoted, and for others to follow, as well as for a fuller discussion of this puzzling question, see Colonel McMahon's excellent paper on the Simla Himalayas, Rec. G. S. I., X, p. 204.

corresponding discordance of original relations in the masses subjected to the disturbing action. For the case in hand no supposition seems so plausible as that already made, that these upper rocks in the actual valley basins were originally laid down in similar deep hollows formed by subaërial erosion in the gneissic series; and that the dislocated upheaved mass of Simla slates, forming the ridge on the south of the Sutlej, was determined in form by an underlying original ridge of the supporting gneissic rocks. The presence of this massive gneiss in the Chor, on the axis of this curved dislocation, is perhaps some support for the explanation offered of the latter feature. This mode of action is also supported by observations made elsewhere, from which it was inferred that compression has a tendency to increase original inequalities of surface.[1]

The junction of the slate and gneiss series in this region is not, however, all of the sharply defined form described in the Sutlej valley, where the massive unaltered limestone dips abruptly towards the massive gneiss. The observation already mentioned, of the Blaini group on a high point north-east of the Sháli, and having a low north-easterly dip, gives us cause to expect that the Król rocks occur in the ascending section in the direction of the high mountains, lofty spurs from which are at no great distance. The same Blaini outcrop has been traced by Colonel McMahon to the south-east across the Thiog ridge into the valley of the Giri, east of which it passes under the Paternála ridge, formed of Król quartzites, to emerge again in the valley under Chepál, whence it is traceable to the Tons at the bridge on the Simla-Mansúri (Mussooree) road. The expectation to find the supra-Blaini rocks inside this line is natural; but the difficulty of recognising them is indefinitely increased by the greater or less metamorphism that all the rocks have undergone in this direction.

A very important first attempt to accomplish this task has been made by Colonel McMahon. He considers that the calcareous schists forming the summit north of Matiáni, on the Simla watershed ridge, east of Sháli, represent the Król limestone; and they pass on to Nárkanda, close under the Hatu summit, formed of the massive gneiss. Similar calcareous and carbonaceous rocks occur in the Sutlej valley, north of Hatu, above and below Kotgarh, and close above the massive gneiss in the gorge of the river. Other identifications have been made in like positions elsewhere, as at the base of the Shankan ridge about Kotkhai and Tirhosh (Taroche), and far up the tortuous valley of the Rupin. The degree of metamorphism these supposed Król beds have undergone is always markedly less than that of the gneissic rocks of the enclosing

[1] Rec. G. S. I., VII, p. 62.

ridges; but the action has been sufficient to amalgamate the two rocks at their junction, so that the detection of their original contact is most difficult. Such crucial sections must, however, be sought for and found, to complete the direct evidence for the proposed relations of the rocks.

Such observations as those now recorded—where top beds of the slate series rest close upon the massive gneiss—imply, not only the removal of the 6,000 feet of schistose gneiss, normally overlying the massive rock in closely adjoining positions, but also the entire overlap of the Simla slates by the Król deposits in the inner area of the mountains; thus completing the picture of the primitive condition of the Simla area—as a great mass of gneissic rocks, deeply eroded by atmospheric denudation, and gradually submerged beneath the palæozoic waters. The idea of the upper gneiss being the Simla slates converted, is hardly to be thought of; a much more probable equivalent for the infra-Blaini beds being found in the silurian slates resting upon that gneiss in Tibet.

Special metmorphism and disturbance.—The extent to which the top beds of the slate series have been locally metamorphosed under different circumstances is well exhibited at Simla itself; the garnetiferous and hornblendic mica schists, with abundance of vein quartz, forming Jako, being undoubtedly converted infra-Król beds, overlying the Blaini group, which is well seen round three sides of the mountain. This feature is in itself most interesting, as shewing that advanced results of metamorphism are brought about independently of any plutonic heat; the Simla slates underlying these highly foliated schists of Jako shew no sign of crystalline metamorphism, although of course they must have had the full benefit of any heat from below that can have been instrumental in producing those effects on the upper rocks. This remarkable case of special metamorphism at Simla was a strong point in the suggestion that even the gneiss of Hatu and elsewhere might really be a later formation than the Król beds, which at so many points seem to pass under it. That suggestion did not necessarily imply that the Król beds maintained their unaltered condition beneath the gneiss; but the proof (p. 597) that this latter rock is the same as the infra-silurian gneiss of the main range, renders the suggestion altogether untenable.

In this connexion notice may be taken of a common structural feature of the hills in this region; how, almost invariably, vertical or highly contorted beds are found in the bottoms of the valleys, whether transverse or longitudinal; while in ascending the slopes the dips become lower, and at top the beds are often quite flat. The usual explanation of this would be that, as the valleys are the result of denudation, erosion had taken place where the strata were most crushed. A quite

opposite interpretation of the facts has been suggested by Colonel McMahon, to shew that more or less of the contortion of these rocks has occurred since the hills and valleys assumed somewhat of their present form:—that, lateral pressure, set up beneath a deeply eroded surface, would take effect in the manner described, crushing the strata in the positions of least resistance, the action being distributed in a diminishing degree up the sides of the hills. Some confirmation of this view may be derived from the fact that great contortion, the result of lateral pressure, has been proved to have taken place in the outer hills since the main features of the Lower Himalayas were carved out (p. 570); and it is by no means unlikely that at the same time some action of the kind supposed occurred in that area.

There is always a risk in applying characters that are obscure, to modify the interpretation of characters that seem plainer; but in complex questions no suggestion should be omitted. Thus the fact that on a commanding summit, some of the highest beds of the whole stratified series are found in a high state of metamorphism, overlying unaltered rocks, and well removed from the area of general metamorphism, seems decidedly at variance with certain views put forward, on page 569, regarding pre-tertiary Himalayan land and the late disturbance of the slate series. The risk here lies in the imperfection of our knowledge regarding the processes of the metamorphism of rocks; but on any supposition, short of some innate form of metamorphic action at this spot, we must connect the fact with the principal disturbance and crushing to which these rocks have been subjected; and it must have been a form of disturbance very different from that suggested in the last paragraph. The same considerations would suggest that, at the time of their metamorphism, these rocks on Jako, and the valleys on both sides, must have been covered by a thickness of deposits of which no account has yet been taken. Or may we reverse the reasoning, and take the fact of the rocks being altered on this peak as a proof of how very superficial a matter thorough metamorphism may be?

Trappean rocks.—The distribution of eruptive rocks in the Simla region is not without its bearing upon the foregoing considerations. On the best known section, that along the road through Simla to Nárkanda, only one thin dyke has been observed near the latter place; whereas in the same rocks of the adjoining area in the Sutlej valley, and again in the basin of the Biás, we find profuse trappean intrusion, evidently connected with the extreme crushing and disturbance the slates and limestone have undergone in those positions; and the same intrusion occurs again freely to the south-east, under like conditions. Trap is rare

in the gneissic series, unless in particular spots, as on the Sutlej between Nogli and Rámpur; and its absence in the slates in the area indicated may be due to an underlying mass of gneiss, such as has been just suggested to account for the peculiar form of dislocation connected with the elevation of that area.

This distribution of the trap, connected with the fact that the slates had not been contorted when the Subáthu deposits were laid down (p. 569), has been taken [1] to prove that the trap of the Lower Himalayas must be at least of post-nummulitic age. That it should so very rarely penetrate the tertiary rocks is rather remarkable (p. 557). Can the explanation of this apparent anomaly be, that the origin of this intrusive rock is rather innate than hypogene? [2]

The Chor mountain.—The most conspicuous summit of what we may still speak of as the Simla region is the Chor mountain, having an elevation close upon 12,000 feet (11,982). It stands between the Giri and the Tons rivers, 25 miles south-east of Simla, and as near to the plains as that station itself. Throughout the whole Lower Himalayas no summit of this elevation is known to occur so near the edge of the mountains. The entire crest is formed of the most massive granitoid gneiss, which, unless repeated by faulting or flexure, must be here at least 5,000 feet thick. The area occupied by this rock is about 10 miles long, from south-east to north-west, by 6 miles broad; it is surrounded by the slate and limestone series.

At first sight, and from the point of view of the slates and the metamorphic series forming an approximately conformable sequence, the feature was most puzzling, as it had to be accounted for in some manner as a protrusion of the basal rock through an enormous thickness of overlying deposits; and accordingly it was so accounted for [3]; a partial resemblance of the cross-section to that of the Dhauladhár was allowed to overrule many almost incompatible facts recorded at the same time,[4] and the Chor was presented as a protruded mass. All the observations we possess of the ground are few and incomplete; but they seem to agree best with the view brought forward by Colonel McMahon, that the Chor was already a mountain in palæozoic times.[5] The ground offers an accessible and compact field for the study of this most interesting question of the relation of the two great rock-series.

[1] Mem. G. S. I., III, Pt. 2, p. 71.
[2] For a parallel case, see Mem. G. S. I., VII, (201)—(203).
[3] Mem. G. S. I., III., Pt. 2, p. 47.
[4] *l. c.*, pp. 41 to 45.
[5] Rec. G. S. I., X, p. 211.

The gneiss of the Chor is highly granitoid and massive. It is certainly generally free from foreign rock, but vein granite has been observed in it.[1] The bedding and foliation can, however, be traced, indicating a low dip to north-north-east; and other features shew this to be the lie of the gneissic mass: on the north, the overlying schists reach farthest up the spurs, and the gneiss farthest down the stream beds; while on the south the highest outcrops of the gneiss area are on the spurs and the schists extend up the valleys. This latter disposition requires that the gneiss to some extent overlies schists; but it has not been made out whether this is by normal superposition, or by inversion of newer beds, or by deformation of an original junction, or by faulting.

On the supposition of this gneiss being protruded from below among the slates, whether in a partially plastic state or by faulting, its neighbourhood should be a position of special disturbance. The contrary is certainly the rule. In ascending from the Giri to the Chor, the Simla slates maintain a moderate dip towards the mountain; they become gradually metamorphosed, and about Banálah and Sohána, close to the gneiss, soft hornblendic garnetiferous mica schists, like those of Jako, are nearly horizontal. Similar beds on the north side form the spur between Mándera and Surán, where they rest upon the porphyritic gneiss. If these beds are indeed of the infra-Król group, the case of overlap and complete unconformity would be established. On the south-east side of the Chor the limestone is in great force, and the disturbance is more marked.

South-east of Simla.—Although the fullest and clearest sections of the upper groups of the slate and limestone series are found in the Simla region, the most complete case of removal of these beds occurs in the same ground; west of the Król, up to Arki, the great Król limestone is wanting, unless it is represented by the narrow band at Kakarhati, on the old road to Simla, the pseudo-organic markings in which rock have often led to a vain search for fossils. The absence of the limestone here is apparently connected with the faulted elevation to the west, described on page 603. South-eastwards from the Król the limestone range is very conspicuous, being sharply defined on the north by a great faulted anticlinal that passes from Kandah Ghât, at the north base of the Król, down the deep valley of the lower Giri. From the confluence of the Palar with the Giri the limestone crosses to the north, and spreads over a large area east of the Chor, to the Deoban mountain (9,347′) in Jaunsár. The boundary with the gneissic series has not been traced

[1] McMahon: *l. c.*, p. 221.

in that direction. Along the ridge at Mansúri (Mussooree) the Król limestone occurs frequently, as on the Abbey and Camel's-back summits. On the top of Landour it is mixed with sandstones, and appears again by itself on the Tapuban point. The Blaini limestone and conglomerate are well seen cn the flanks of the Sirkanda summit, and again in the Ganges at its confluence with the Hinnalgár. Intrusive trap is not uncommon in the slates at Mussooree.

Kumaun and Garhwal.—As the earliest British possession in the Himalayas, the province of Garhwal and Kumaun was the first open to systematic observation. Indeed, the first attempt at official geological survey work in India was the mineralogical survey of this ground, undertaken by Captain Herbert by order of the Governor General (Lord Hastings). The work was finished in 1825, but was not published till 1842,[1] nine years after the death of Captain Herbert. As the work of an accomplished man, fairly versed in the science of his day, Captain Herbert's report is of permanent interest for students of geology in India, as the best local illustration of the state of geology at that time.

A quarter of a century later it was again on this ground that a connected geological survey on a large scale was undertaken by Captain Richard Strachey, of the Bengal Engineers, now General Strachey. His map includes the same area of the Lower Himalayas as Captain Herbert's, between the Sutlej and Nepál, with the important addition of a broad band in the Tibetan region. A comparison of the two works gives an instructive illustration of the advance made by geological science in the interval. With some few exceptions, our remarks on this portion of the Lower Himalayas are taken from General Strachey's observations.[2]

The section through Naini Tál and Almora presents some analogies with the Simla section. The ridge at Naini Tál is a great synclinal range, with many local fractures and contortions, like its type the Król range. The great limestone that forms many of the summits to the south of the lake is very like the Król limestone; and the pink, greenish and dark-grey shaly slates associated with it shew the same affinities. A conglomerate like the Blaini rock has been observed in the dark slates forming the ridge north of the Kota dún. One observation, indeed, has been recorded throwing doubt upon this correlation: the Messrs. Schlagintweit announced [3] the discovery "in the clay-slates in the neighbourhood of Naini Tál of numerous *Foraminifera*, evidently identical

[1] As an extra number of Vol. XI of the Journal of the Asiatic Society of Bengal. The map to illustrate the report was issued with Vol. XIII, 1844.

[2] Q. J. G. S., Vols. VII and X, 1851 and 1854.

[3] J. A. S. B., XXV, p. 118.

with those which accompany the eocene nummulitic formation." It is possible that these explorers may have hit upon a remnant of the Subáthu beds, folded up in the slates, like those mentioned in the Sirmúr area (p. 534), and the one case east of the Ganges (p. 535); but it is also possible that the oolitic or other concretionary forms, common in the limestone at Naini Tál as at the Król, may have been mistaken for fossils. Numerous careful observers have searched the rocks in vain to verify the Messrs. Schlagintweit's discovery.[1]

North of the limestone range there is a great dislocation with upheaval to the north, as at the Król. But in Kumaun, at least on this section, the line of fracture is filled with a basic eruptive rock, numerous dykes of which occur in the range about Naini Tál. It is apparently on the south-eastern continuation of this main intrusion that the igneous rock which penetrates the sandstones of the Sub-Himalayan zone (p. 543) is described as taking the form of a granite.[2] It is stated that the limestone occurs again to the east of this great line of intrusive rock.

North of the dislocation the contrast with the Simla section is most marked: we come at once upon thorough metamorphic strata, genuine schists, like the older series of the Simla region, rather than like any known metamorphic condition of the slate series. The strata maintain a steady, moderate north-easterly dip, thus presenting a very marked decrease of disturbance as compared with the newer rocks. This was also a point of contrast between the two series in the Simla region. In Kumaun, too, trap rock is comparatively rare in the gneissic series. South of Almora (the capital of Kumaun) a broad band of granitic rock occurs in the schists, and has a considerable range to south-east and north-west. It seems to be in the main a massive granitoid gneiss; but some true vein granite occurs with it. Mica schists occur again north of the granitoid rock, containing strings and nests of impure graphite, the north-easterly dip being continued; after a space the same beds turn up, with a south-westerly dip. North of the synclinal there is a marked line of disruption, with copious intrusion of trappean rock and the introduction of new strata—slates, conglomerates, and quartzites, with limestone in force. Disturbance is, again, more varied and more marked in these formations, and it is not unlikely that they may ultimately be identified with the slate and limestone series of the Simla region, though no specific attempt can now be made at affiliation. Beyond these, again,

[1] There is also a possibility, as in the case of the triassic limestone, said to have been found by one of the same collectors near Solan, and in numerous examples amongst their zoological collections, that there was a mistake about the locality of the specimen.

[2] Q. J. G. S., 1851, VII, p. 298.

there is a region of crystalline schists at the base of the great snowy range.

Nepal.—From the borders of Kumaun we have to pass by a blank of 250 miles to get our next glimpse at the rocks of the Lower Himalayas, on the Kathmándu section.[1] The length of this section is about 30 miles, from the main boundary; which distance would nearly take us to the second line of dislocation and intrusion north of Almora in Kumaun, and as far as Nárkanda in the Simla section. Except in the conjectural identification of the formations, the features are unlike those described in the western area.

The first rocks seen north of the tertiary sandstone are some earthy schists, having a crushed dip of 50° to north-by-east, quite parallel in strike to the sandstone and to the boundary. A thin band of blue limestone occurs in these beds; and further on, a thick band of black schistose slates, in which are some irregular layers of impure coaly matter. All these beds, though decidedly sub-foliated, are less altered than any rocks to the north of them, and also less highly inclined. After some special contortion and folding, connected with which a doubtfully intrusive trappoid rock was observed, the schists are succeeded by a broad band of quartzites; and these again by a great mass of white crystalline limestone, all dipping at 70° to 80°, to north by east. A specimen of this rock proved to be not dolomitic.

This great band of limestone would seem to end the ascending section; for over a broad area on the north this limestone and the quartzite are repeated in broken confused masses, as if in a synclinal flexure, forming the most wild and picturesque portion of the Rápti valley, below Nimbua Tanr.

The resemblance of this series to that of the Król and infra-Król rocks, is quite sufficient to warrant the supposition of their connexion; and even the form of the section, so far, is homologous with the corresponding portion of the western sections. The greatly advanced metamorphism and the excessive disturbance are the chief points of contrast.

At the head of the Rápti valley, about Bimphédi, there is an abrupt change of the strike, to north-35°-west, in flaggy quartzose schists; and in the Chessagarhi ridge these rocks are associated with thick bands of porphyritic gneiss, which becomes dominant at the north base of the ridge. On this side the change is abrupt, from the gneiss to a great series of flaggy and slaty schists occupying the Pinauni and Chitlong valleys. The dips are in opposite directions in the gneiss and the schists close to their junction, suggesting that the gneiss had been faulted up

[1] Rec. G. S. I., VIII, p. 93.

along a broken anticlinal. With slight variations, there is a steady ascending section of the flaggy schists up to the Chendragiri ridge, overlooking the valley of Nepál; and here again we come upon calcareous rocks, which occupy the whole width of the Nepál valley. It is a broad synclinal, with repeated minor compressed flexures of these upper rocks. Pure limestone occurs chiefly towards the top of the series, as the white crystalline rock at the summit of Phulchók (9,720′) and elsewhere; but there is a great thickness of strata, in which the calcareous element is subordinate, the prevailing variety being a massive, very fine, schistose quartzite, with only a small percentage of carbonate of lime.

It is not a very forced supposition to conjecture that these Nepál rocks are the same as those south of the Chessagarhi ridge, and represent the Król series. The change of composition is even analogous to that observed between the Król and the ground at and north of Simla. The flaggy schists of Chitlong would fittingly represent the Simla slates.

Crystalline schists rise again, more or less vertically, on the north-north-east side of the valley, apparently in descending sequence with the calcareous formation, and at first alternating with the coarse, felspathic gneiss forming the lofty Sheopuri ridge. To the north-west, slaty schists come in again at the inner base of the Sheopuri ridge, and have a decided southerly underlie towards the gneiss. In the valleys of the Tádi and Trisulganga the strike of these schists changes to east-north-east, and calcareous rocks occur with them. The Sheopuri gneiss probably does not cross the Trisulganga.

It is doubtful whether the gneiss of the Chessagarhi or Sheopuri ridges represents the old gneiss of the western sections. Its structural relation to the schist and limestone series is quite different. No granitic vein-rock was observed in connection with it. It is also noteworthy that no trappean eruptive rock occurs in these sections, except in the doubtful case already mentioned near the main boundary, although the rocks are so universally contorted. The fact is apparently adverse to the conjecture hazarded (p. 607) upon the quasi-innate nature of trap in the western region.

The Sikkim area.—Passing over another reach of forbidden ground, 250 miles long, in Eastern Nepál, the Lower Himalayas are again accessible in Sikkim, and we find an immense change in the aspect of the rocks. There is no calcareous group, and all the rocks are more or less metamorphic; but their arrangement is very different from that seen in the Kathmándu section, and superficially more like that of the Simla region.

The first observation of importance in this ground was the discovery by Dr. Hooker, in 1849, of rocks containing fossil plants of the Damúda formation at the base of the Sikkim hills.[1] This still remains the only case of identification between the pre-tertiary rocks of peninsular India and of the Lower Himalayas; and while we are shut out from observation in Nepál, nothing can be done to follow up this clue towards a fuller correlation of the formations in the two areas.

In 1874, Mr. F. R. Mallet was deputed to examine the ground with a view to the possible discovery of useful coal-seams in the Damúda rocks. Several seams of workable dimensions were found, but the strata have been subjected to such compression and contortion, that the coal is everywhere reduced to a flaky crumbling state, so that it could only be used after artificial consolidation. The broken condition of the rocks would also make mining very difficult. Mr. Mallet has, however, given a description of the rocks that deserves careful attention.[2] His observations extended along the fringe of the hills through the Western Bhútan Duárs to the Sankos river, near longitude 90°; but as there is a striking contrast in the rocks to east and west of the Jaldoka, forming the boundary of Sikkim on the east, the descriptions had better be given separately.

The Sikkim area is more than 90 miles long, from the Mechi on the west, at the Nepál frontier, to the Jaldoka on the east. The Tista (Teesta) river, flowing from the great snowy range, divides this area about equally into the Darjiling division on the west and the Dáling on the east. North of Darjiling lies the broad and deep valley of the Rangit; while the Tista and the Rangchu form a similar deep depression north of the Dáling area, the combined effect being that of two broad lofty spurs confronting each other on opposite sides of the lower gorge of the Tista.

There are three series of rocks within the area specified: a gneissic series, forming the whole of the mountain masses above 2,000 to 3,000 feet in elevation, and called the Darjiling gneiss; a great thickness of schist and slate, called the Dáling series, extending not only along the outer border of the mountains, but up the gorge of the Tista and round into the valleys of the Rangit and Rangchu; and the Damúdas, forming the third series of the Lower Himalayan rocks in Sikkim. The last-named are only found at the outer edge of the mountains, their greatest inward extension being a short way up the valley of the Tista, where of course the deepest section of the rocks occurs. The Damúda outcrop dies out within the limits of the Sikkim border: on the west it

[1] Himalayan Journals, Vol. I, p. 402,
[2] Mem. G. S. I., XI, Pt. 1.

cannot be traced beyond the Bálásan river, 4 miles short of the Nepál frontier. To the east it has not been with certainty traced beyond the Chel, south of Dáling, one of the positions already noticed where the tertiary rocks have been totally removed or concealed. The Dáling slates at this point form a promontory, reaching quite up to the usual line of the outer edge of the tertiary zone.

The Darjiling gneiss.—True gneiss is the preponderating rock of the gneissic series, but it often passes into gneissose schist and mica schist; bands of quartzite occur rarely, and hornblendic rocks are extremely uncommon; limestone or dolomite is unknown, and the gneiss is quartzose and never granitoid. Almost the only accessory minerals are kyanite, schorl, and garnet. Several of these characters distinguish this gneiss very decidedly from the gneiss of the peninsula, which is well represented close to the Himalayan border in the hills of Lower Assam. Except for the absence in Sikkim of the massive granitoid band, the Darjiling gneiss would fairly represent the gneiss of the Simla region. No observer in Sikkim has suggested the presence of two gneissic series. In the snowy range near Kanchinjinga Dr. Hooker has described this rock as penetrated by granite veins; but this, as we have remarked (p. 597), gives no grounds for its separation. The age of the gneiss in the great range of the Eastern Himalayas has not been proved; but there is no presumption that it is different from the infra-silurian gneiss in a corresponding position to the north-west; and thus there is a decided presumption against the Darjiling gneiss being formed of strata of the secondary period, as it must be if its apparent relation to the other formations is the true one. At the same time, the rocks of the two areas have never been examined by the same observer.

On the main northern road through Darjiling the gneissic area is 16 miles across, and the strata have the form of a broad flat synclinal, with numerous minor internal foldings. On the eastern slope also, over the Tista, the dip is inwards (westerly). A like arrangement is observed in the gneiss of the Dáling spur.

The Daling series.—Pale-green smooth slates or clay-slates are the prevailing rocks of the Dáling series in its lower outcrops, next the Damúdas; but sometimes, in this position, they are quite schistose. Darker bands occur, also some flaggy quartzites, and rare beds of hornblendic schist, which is sometimes calcareous or dolomitic; but the almost complete absence of lime is a character of the series. Beds of carbonaceous or graphitic schist are occasionally found in the Dáling series, as on the road above Pankabári, and a little south of the cart-road at Kurseong. West of the Máhánadi the beds next the Damúdas are more

earthy and arenaceous, and a slaty conglomerate occurs near, or at, the boundary. On approaching the gneiss there is always a marked increase of metamorphism. In the outer (southern) sections this apparent passage into the crystalline series is comparatively rapid; while in the interior the metamorphism of the slates near the gneiss is more pronounced, more gneissose beds appearing in them; so that the distinction of the two series is less marked.

In both the Darjiling and Dáling areas, the dip of the slates is constantly towards the gneiss, thus conforming regularly to the converging dip described in this rock, and thus completing the appearance that the Dáling series normally underlies the gneiss in a continuous transitional sequence. Only for a portion of the boundary north of Darjiling, in the Little Rangit and on the Takvor spur, an appearance of faulting between the two series was observed. From the recorded arrangement of the rocks, it appears as if the lower gorge of the Tísta lies in a broad tranverse anticlinal curve of the strata.

The Damuda series.—In some sections, as on the cart-road to Darjiling, the Damúdas have undergone little or no alteration, and their resemblance to the regular Gondwána coal-measures is very marked. The sandstones, as a rule, are rather fine-grained; they sometimes occur in thick masses, but coarse, white, felspathic sandstones of the Barákar type are not common; the beds are occasionally calcareous, and conglomerates are absent. In these characters they resemble rather the upper measures of the Damúda coal basins. The fossils as yet found comprise two species of *Glossopteris* (one is *G. browniana*), *Vertebraria*, an equisetaceous stem referred to *Phyllotheca*, and *Sphenophyllum speciosum*. Frequently, however, the Damúda rocks exhibit as much alteration as the contiguous Dálings, as west of Pankabári, and in the Rangichang east of Pankabári; the sandstones being converted into hard quartzites and the shales into dark slates and graphitic schists. In this respect, the contrast with the contiguous tertiary rocks is important; these, although greatly disturbed and compressed, never shew signs of mineral alteration.

It would be difficult to assign a thickness for the Damúda formation in this ground. The broadest section of the outcrop is at the Tísta, about one mile long; and the beds have a high dip (more than 60°) throughout, but in very various directions. The prevailing dip is inwards, towards the mountains, and almost always so near the Dálings, the stratification in the two formations being constantly parallel.

Relations of the three series in Sikkim.—The conclusions which Mr. Mallet has adopted regarding the relations of these three rock-series are: that they form a continuous stratigraphical sequence, the gneiss being

the newest and the Damúdas the oldest. This is undoubtedly the apparent reading of the recorded observations; and considered by itself, without reference to other Himalayan sections, the objection to it was more or less a theoretical one—the occurrence of a completely metamorphosed formation above absolutely unaltered deposits. Mr. Mallet did not, of course, suppose that the Damúdas passed beneath the mountain area with no greater change of texture than they exhibit at the outcrop on the edge of that area; even the Dáling slates are more schistose in the interior valleys than along the outer scarp of the mountains; still, if the apparent sequence of the rocks were true, the anomaly, on a very large scale, had to be accounted for, and the explanation of it offered by Mr. Mallet (*l. c.*, p. 42) is certainly a *vera causa*, within unknown limits, in adopting which he was much encouraged by known precedents—the thoroughly crystalline schists (*supra*-Blaini) forming Jako mountain at Simla, overlying slates that are not even sub-schistose; and, the then open question whether the Król series did not really pass under the gneiss of Jalóri and of Hatu (p. 605). The subsequent demonstration by Colonel MacMahon, that the gneiss of the Simla region is *infra*-silurian, made this latter supposition untenable; and other explanations, seemingly more far-fetched, had to be adopted for that ground, regarding the relation of the two great rock-series.

This experience in the Simla region compels us to scrutinise more closely the observations in Sikkim, and to indicate what possible alternatives there are to the view at present set forth. We have three series to deal with here, which may rather help the discussion; but we have not the advantage of knowing the normal (original) order of sequence in any of them, as was the case with the slate and limestone series in the north-west; so that in Sikkim we have no direct criterion as to inversion, or otherwise, in any particular position.

Out of all the observations recorded bearing upon this question, only one gives certain evidence upon the original relations of these formations. The opinion that the Dálings normally underlie the Darjiling gneiss is altogether inferential, from the lie of the rocks of both series in adjoining positions, no actual section of the junction having been seen. It may, indeed, be granted that if the gneiss does overlie the Dáling series, it does so in normal sequence, inversion in this form and of such magnitude being out of the question; and this is a crucial point in the argument, for it can be said (from the evidence of our one sure section) that if the gneiss does overlie the Dálings, the Damúdas must normally underlie them, as otherwise the gneiss must be converted Damúdas, which is an untenable view.

The crucial section referred to is that in the Lehti stream (*l. c.*, pp. 28 and 39), just west of the promontory of slates south of Dáling. Here we have a continuous section showing the original relation of the Damúda and Dáling series to be complete conformity and association by interstratification, several hundred feet of each series being exposed. Nothing can shake the fact derived from this section (assuming it to be correctly described), that the two formations are conformably associated; and this disposes of one of the possible conjectures regarding the boundary—that the Damúdas were deposited against a steep bank of the slates, as is thought to be the case with the boundary of the tertiary series. The junction observed in the Lehti section may, moreover, be one of extreme chronological importance; for if the Dáling slates should be ultimately proved to be the same as the middle palæozoic slates of the Simla region, the Damúda beds so closely associated with them can scarcely be newer than upper palæozoic. The other important features of the Lehti section are, that the dip is steady and low (30°); that its inclination is to the south; and that the Damúdas overlie the Dálings. As the balance of evidence from all the other sections, and the decision regarding the slate and gneiss boundary, indicated or required that the Damúdas should underlie the Dálings, this section in the Lehti had to be considered as inverted, in spite of its unbroken low dip, and southerly inclination, which would require, or at least suggest, that the inverting thrust had been directed from the south. It is true that the Damúdas here are in their most altered condition, comprising quartzose and carbonaceous schists, with thin seams of the flaky anthractic coal; but the action of metamorphism is too capricious and untraceable to carry much weight in an argument against clear mechanical conditions.

We have already seen an instance (p. 537) in which one clear section was held valid against any amount of conflicting appearances. This Lehti section is not of the same decisive nature as the case referred to, but it certainly suggests the necessity of a close revision of the interpretation set forth for these intricate stratigraphical features. If it should be upheld as the standard section, as shewing that the Damúdas normally overlie the Dálings, all the other sections of this junction must be regarded as inversions; and the slate and gneiss boundary must be one of great unconformity or of great faulting; for, as already mentioned, it is scarcely possible that the gneiss should be converted Damúdas. This slate and gneiss boundary (p. 615) is, perhaps, the less difficult of the two, for its features are exactly similar to those in the Biás and Sutlej valleys of the Simla region (p. 602), where the fault or unconformity explanation had to be adopted. The greater difficulty is to shew how, on the

supposition of inversion, the Damúda outcrop could assume the form it has; such as, its greatest inward extension in the Tista valley, on what is taken to be an anticlinal axis of the slates. This extension on the denuded anticlinal axis is exactly what would occur if the Dálings overlaid the Damúdas normally, without inversion.

Another supposition is evidently possible: The unconformity view may be adopted, as in the North-West, for the Dáling and gneiss relation; and still the Damúdas may normally underlie the Dálings, and be altogether overlapped by these, low down (underground) on the flanks of the gneissic masses. But in this case also the section in the Lehti must be an inversion.

The reader will probably admit that the interpretation of the Sikkim sections is still an open question; and he will also recognise how very precarious any attempt must be to correlate these rocks with those of the Lower Himalayas of the North-West: the only conjectures possible are, that the Darjiling gneiss probably represents the central gneiss, and that the Dálings possibly represent the Simla slates, in which case the Damúdas must overlie them.

The Bhutan border—Buxa series.—Colonel Godwin-Austen was the first observer in this ground (1865-68); when he brought to notice [1] its peculiar features—the local concealment or absence of the tertiary rocks, and the presence in force of dolomites that are not represented in the Sikkim sections. Mr. Mallet's connected observations of the two areas were necessarily too rapid to admit of more than a suggested correlation of these adjoining and contrasting sections. The superficial view of the case (from the maps) would be, that these new rocks in the Bhútán Duárs take the place of the Damúdas in the Sikkim ground.

Mr. Mallet gave the name of Baxa series to this new formation, from the well-known Bhútánese fort which is built upon it. The fullest section given is that in the Titi stream (20 miles west of Baxa), as follows (in apparent natural order):—

(*f*).—Dark-grey slates; pyritous and rusty	300
(*e*).—Dolomite, with layers of dark-grey slate	1,500
(*d*).—Green, black and red slates, with flaggy quartzite, chloritic schist, and flaggy calcareous beds at top	1,500
(*c*).—White quartzite, locally flaggy and schistose	1,000
(*b*).—Slates with flaggy silicious and calcareous layers	800
(*a*).—Green and red slates	500

The thicknesses are only eye-estimates, the dip being pretty steady at 60°, to north-north-east. In the Jángti (3 miles east of Baxa) the

[1] J. A. S. B., XXXIV, Pt. 2, p. 106, and XXXVII, Pt. 2, p. 117.

apparent thickness of the dolomite band is 2,300 feet. Owing, however, to faulting or contortion, with denudation and concealment, this rock is locally absent from the exposed outcrop of the series, as in the space of 15 miles between Baxa and the Tursa. Carbonaceous schists were observed low in the series in the Raidak stream (10 miles east of Baxa).

Owing to the restrictions against entering the Bhútánese territory, Mr. Mallet was not able to examine the inner boundary of the Baxa series where it is fully developed, but it seems there to underlie a broad belt of slates and schists intervening between it and the gneiss, and probably representing the Dáling series. This was also observed at a point 30 miles west of Baxa, where the Baxa series ends abruptly in the surface gravels: the Dáling slates are seen in the Jángti river at a short distance off, and they seem to pass inside and to overlie the ridge of Baxa rocks. From this point to the Jaldoka at the Sikkim boundary, the hills are altogether inside the Bhútan border, and thus inaccessible.

Between the Sikkim boundary and the promontory of Dáling slates there is a short space, 6 miles long, where some of the tertiary rocks are represented; and between them and the Dáling zone Mr. Mallet found beds representing both the Damúda and Baxa series, but not in the same section. In the Mochu, on the west, just below the Dálings, dipping north-east at 60°, there are coarse and fine sandstones, shaly and slaty beds, and two or three coal-seams of about a foot in thickness. These are undoubtedly Damúdas; but the rocks below them are not exposed. At 3 miles to the east, in the Máchu, some beds, including carbonaceous layers, are obscurely seen underlying very brittle silicious flags, with pink calcareous layers, and a few of red shale, dipping north-north-west at 50°. Beyond these, and apparently overlying them, are green slates of the Dáling type. The middle beds of this section are quite of the Baxa type, and unlike anything known in the Dálings; and the carbonaceous layers at the base are not more carbonaceous than some found in the Baxa area.

Independently of any direct identification of these carbonaceous layers in the Máchu as Damúda, which would shew a distinct incipient intercalation of the Baxa beds between the Dálings and the Damúdas, and a horizontal association and transition between the Damúda and the Baxa deposits, the general comparison of the sections seem to suggest no other supposition than that these two series are in some manner representative of each other. The observations in hand do not admit of any further discussion of the question.

The Dikrang section.—After so complete a change as that from the Damúda coal-measures of Sikkim, to a great mixed series of deposits like that of Buxa, it might certainly be expected that the alteration would be permanent, and that the Buxa type of deposits would continue to the eastward; yet in the next observation we obtain of the Lower Himalayan rocks, the section is more like that in Sikkim than any other. The locality is more than 250 miles to the east of Buxa, in the Dikráng valley, inhabited by the Daphla tribes, where Colonel Godwin-Austen has described,[1] immediately inside the tertiary zone, a belt, about 1,000 feet in thickness, of dark, hard sandstones with carbonaceous shales and seams of crushed flaky coal. No fossils were secured, but the probability is strong that the group represents the Damúda formation. The beds are more or less vertical, with a north-east strike; and they are bounded on the north-west by a parallel series of white quartzitic beds with micaceous and hornblendic schists, passing by degrees into gneiss, which in turn becomes highly granitoid. Had there been anywhere near this ground any development of so conspicuous a rock as the dolomites, they would surely have been noticed by so practised an observer; so the presumption is fair that the schists next the Damúda band represent the Dáling rocks. Thus, again, the disappearance of the Baxa series and the reappearance of the Damúdas in its place, is some slight confirmation of the conjecture hazarded, that these two formations are in some manner equivalent.

Summary.—All the conclusions suggested by our study of the Sub-Himalayan rocks, and summarised at the end of Chapter XXIII, have more or less bearing upon the contiguous Lower Himalayan area, and indeed upon the whole mountain region: any additional remarks derivable from this latter area only, must refer to the earliest periods of our history, or, indeed, to pre-Himalayan time, for all the formations concerned are probably not newer than palæozoic.

From end to end of the range (very imperfectly known on the east) we have found two great rock-series, a slaty and a gneissic. For 500 miles in the middle of the range we have but one section, reaching only to 30 miles from the south border; and it is, perhaps, doubtful whether the gneiss described in that section belongs to the older series (p. 612).

In the Simla region, at the north-west termination of the Lower Himalayas, a strong case has been made out for very great unconformity between the two series, shewing the palæozoic rocks to have been

[1] J. A. S. B., Vol. XLIV, Pt. 2, p. 35.

deposited upon and against a very deeply and irregularly eroded surface of the old gneissic series (p. 605); to which circumstance may be attributed the very partial manner in which the contortion of the rocks of the Lower Himalayan area has conformed to the normal lines of Himalayan disturbance.

Structural features homologous to those of the Simla ground have been provisionally indicated in the east, in Sikkim (p. 617). Should this relation of the two series be established throughout the range, a connexion will have been made out between this peculiar Lower Himalayan region and a primitive gneissic mass, forming a fundamental nucleus for the whole series of Himalayan formations. The presence of this barrier may help in the explanation of the strange contrast presented by the fossiliferous deposits on the north, and the azoic characters of what are probably the equivalent strata on the south, even though we find that these deposits were continuously connected to the north-west.

What may have been the original southern extension of the great slate and limestone series of the Lower Himalayan area is at present a matter of pure conjecture. Considering, on the one hand, the close connexion of the Damúdas with the Lower Himalayan slates, and, on the other, the prodigious break in time between the Gondwánas and the Vindhyans of the peninsular area, it does not seem likely that the latter formation can have any representative in the newer series of the Lower Himalayan area.

CHAPTER XXVI.

EXTRA-PENINSULAR AREA.

CENTRAL (TIBETAN) HIMALAYAS.

Data available — Classification of rocks — General structure and distribution — The main gneissic axis — The Ladák axis — The Hundes and Zánskár synclinal — The Kárákoram synclinal and Kuenlun axis — The Kashmir synclinal — Position of the tertiary rocks — Gneiss of two ages — The central gneiss — Mineral character — Stratigraphical relation — Relations defined only in the middle Himalayas — The granitic axis — Terminal extensions of the central gneiss — The Zánskár gneiss — The Pir Panjál gneissic chain — The Dhauladhár gneissic range — The newer gneiss — The chief sedimentary basins. The formations of the Zánskár area — Palæozoic series — South-west boundary — South-east boundary — The Rupshu metamorphics — North boundary with tertiary rocks—The secondary series — The tertiary series.

Data available.—As the title of this section of our work would be understood to include all of the Himalayan region not described in the preceding chapters, we must at once call attention to the small portion of that enormous area of which any trustworthy observations have been made, and of which only any notice will be taken. Of the two southern divisions of the region, the Sub-Himalayan and the Lower Himalayan, comparable sections were given, extending nearly to the eastern end of the Himalayan ranges, though with very long blank intervals. Of the entire eastern half of the central area, we have only to record Dr. Hooker's observation[1] within the frontier of Tibet, north of Sikkim and of the gneissic axis, that conglomerates, slates, and red clays were found overlying the gneiss; and further on, a dark limestone "full of encrinitic fossils and probably nummulites, but all were too much altered for determination." All the great peaks are said to be formed of granite or of massive gneiss.

On the west of the unknown area of Nepál, General R. Strachey has described the country[2] from the watershed at Lake Mánasaraur (Manasarowar), elevation 15,200 feet, in about longitude 81° 30', and has given an account of part of Hundes or Ngári-Khorsum, in the upper valley of the Sutlej, as far as the place where this river enters the transverse gorge, about Shipki.

[1] Himalayan Journals, Vol. II, pp. 156 and 177.
[2] Q. J. G. S., VII, 1851, p. 292; and X, 1854, p. 249.

This position immediately adjoins the ground of which a more detailed examination was made by Dr. Stoliczka[1] during the summers of 1864 and 1865, extending from the Sutlej to the Drás river. Neither of these descriptions extends northwards much beyond the right bank of the Indus, which river occupies a nearly central position in the region we have provisionally adopted as the Central Himalayas. For the northern portion of this ground, including the Kárákoram and Ḳuenlun ranges, our information is derived from the traverse made of it by Dr. Stoliczka on his journey to Káshghár in 1873-74.[2] The latest additions to the geology of the Central Himalayan region are by Mr. Lydekker in the neighbourhood of Kashmir.[3]

Thus it is seen that our materials refer almost entirely to the north-western, sub-terminal, portion of the Central Himalayas. It is in the near extension of this ground, where the main geological axes of the Himalayas seem to be more or less continuous with those of the Hindu Kush, that the battle of the mountain systems (p. 518) must be fought out. While the facts upon which the question can be decided are unknown, it is difficult to take any interest in discussing it.

Classification of rocks.—In our description of the two preceding divisions of the Himalayan region, we have been forced to depend almost exclusively upon stratigraphical characters, the rocks of the Lower Himalayas having proved unfossiliferous; and even in the tertiary Sub-Himalayan series the occurrence of fossils is so irregular, and the exact sequence of the known fossils is still so uncertain in detail, that but little use could be made of them in tracing horizons throughout so great an accumulation of deposits. Our knowledge of the Central Himalayas may almost be said to err in the opposite direction. In consequence partly, no doubt, of the explorer's attention having been especially directed to palæontological investigation, but still more as a result of the great difficulties of moving about in such rugged ground, and under such trying atmospherical conditions, our information of the central region is decidedly deficient in critical stratigraphical observations. But few will complain of this when palæontological information is forthcoming; and on this score the results already obtained are highly satisfactory. In proportion to the time devoted to this ground, the knowledge we possess of it gives a striking instance of what a master-key palæontology is in geological researches. It is sad to have to record that the master who applied that

[1] Mem. G. S. I., Vol. V, pp. 1 and 337.

[2] Rec. G. S. I., Vol. VII, pp. 12, 49, 51; and Scientific Results of the Second Yárkand Mission: Geology: Calcutta, 1878.

[3] Rec. G. S. I., 1878, Vol. XI, p. 30.

key to the geology of this region lost his life in those researches. Dr. Ferdinand Stoliczka was buried at Leh, in the very centre of the field of his achievements.

In one respect, that of the unaccountable absence or rarity of fossil remains, the slate and limestone series of the Lower Himalayas exhibit an obscure relationship to the old formations of the Peninsula; although, as regards petrological characters, the rocks of the two areas are entirely dissimilar. This azoic condition holds good for those same formations along the whole south face of the Himalayas, in their extension to the north-west of the Lower Himalayan area, along the flanks of the Dhauladhár and the Pir Panjál. It is true these rocks in that position are greatly compressed and more or less altered, but certainly not so as to obliterate all trace of fossils, had any been present in them. Already on crossing the Pir Panjál into Kashmir, fossils are found in the carboniferous limestone, sandstone and shales, which are with much probability taken to represent the upper portion of the series to the south. Still here the underlying silurian slates have as yet yielded no fossils. It is only on crossing the higher range into Tibet that the series of marine fossiliferous deposits can be fully recognised. Through this ground the geology of India can be brought into relation with the rest of the world: all the principal formations of the established stratigraphical scale, except the cambrian, devonian, permian, and neocomian, have been identified. The detailed sequence of formations will be given in connexion with the separate areas in which they were observed.

General structure and distribution.—Considering the immense range of formations—metamorphic, palæozoic, and mesozoic—represented in the sections of the North-West Himalayas, the general uniformity of distribution and symmetry of arrangement, so far observed, give much promise that, ultimately, a very complete history of the region can be made out. From end to end of the partially known ground, about 500 miles, two gneissic axes are more or less continuous.

The main gneissic axis.—The southern of these is the Himalayan range proper, of which, in Sikkim and again west of Nepál for 300 miles, gneiss is the predominant rock, many of the highest and most massive peaks being formed of it; while the slates on the north sometimes run up to an equal altitude, and the passes, through the continuous line of greatest elevation (the watershed), are generally to the north even of these slates. North of the Simla region, corresponding with the termination of the Lower Himalayan area, this main gneissic range divides into three, two of which come to an end well within the Himalayan limits; the third probably does so too, but it has not been traced so far.

The Ladak axis.—The second gneissic axis runs parallel to the first, at a distance of 50 to 80 miles. It has only been observed with any accuracy in Ladák, where it forms a steady range of moderate elevation, separating the Indus from its tributary, the Shaiok (Shyok), and the Pángkong lake. The continuation of this gneiss to the north-west would run high up on the south flank, if not to the crest, of the great Mustágh range in Baltistán, or Little Tibet. To the south-east the Ladák gneiss passes, on both sides of the Indus, through Rupshu into Chinese Tibet. This delineation includes the Rupshu metamorphics with those of the Ladák range, as they are only separated by the nummulitic trough and the tertiary axis of eruption of the Indus valley. Their possible, or even probable, distinction will be indicated further on.

The few names that have been current for the leading features of these mountains are often very inappropriate even for geographical purposes; and for geological description, they are altogether inadequate. Indeed the familiar remark, denoting the close connexion between surface features and the rocks, has a partial lithological application, rather than a geological one; for in the latter sense the idea would often be radically deceptive, as in the case before us: this gneiss of Ladák is geologically an axis of elevation; but although more steady in its course, it is less elevated than the mountains formed of much newer rocks on either side of it; it coincides in part with the actual valley of the Upper Indus. We will avoid confusion with geographical names by calling it the Ladák gneissic axis.

The Hundes and Zanskar synclinal.—Between these two gneissic axes there is a long synclinal basin in which the fossiliferous rocks are found in more or less complete sequence, according to original variations of deposition and the subsequent action of denudation. This feature is not, however, unbroken from end to end of the known ground; at long intervals the basin is more or less completely constricted or interrupted by transverse upheaval and metamorphism of the rocks. A principal break of this kind occurs where the Sutlej bends southwards at the Purgial mountain, which separates the Hundes area from that to the north-west, the secondary formations at least being completely interrupted. It was in this north-western area that Dr. Stoliczka studied the rocks, principally in the Spiti valley, at the south-east extremity of the basin, for which an appropriate name may be taken from the larger and more central district of Zánskár. The length of the basin is about 200 miles, ending abruptly east of the Drás river in a transverse mass of syenitic metamorphic rocks. The valleys of Astor and Gilgit, between which places the Indus has a north and south course, are

on the prolongation of this synclinal axis of Zánskár, beyond the crystalline rocks forming the mountains round the Deosai plateau. Nothing definite is known regarding the extension of the sedimentary series to the east of Hundes; but it is presumable, as Dr. Hooker conjectured, that the unaltered rocks observed by him north of the great gneissic range in Sikkim are more or less a continuation of those in a similar position in the North-Western Himalayas.

The Karakoram synclinal and Kuenlun axis.—North of the Ladák gneissic axis the same sedimentary series comes in again in force, but in this direction some of the upper groups of the series have not yet been identified. This area also is a broad synclinal basin, the newest rocks being found in the centre of it, in the Kárákoram ridge, and the older formations rise again to the north against a third gneissic axis, forming the core of the Kuenlun range. The direction of this range seems to be more east and west than that of the Himalayan ranges proper; so that, if the gneissic axes continued to the west, the sedimentary basin of the Kárákoram would soon be cut off in that direction; while to the east it expands rapidly.

The Kashmir synclinal.—South of the Zánskár basin, and between the diverging prolongations of the gneiss of the main Himalayan range, there is a minor synclinal basin of unaltered rocks, that of Kashmir and Pángi, divided by a transverse mass of metamorphic strata.

Position of the tertiary formations.—The one great exception to the general structural symmetry of the Himalayan formations is the distribution of the tertiary rocks. The nummulitic deposits are not found in the middle of the synclinal basins, in sequence with the upper secondary deposits: they seem, on the contrary, to be as far as possible out of connexion with the general sedimentary series, occupying, as they do, a long trough in the Indus valley, in or adjoining the metamorphic rocks of the Ladák gneissic axis. This feature is so very marked, as laid down for 200 miles, between Hánle and Kargil, by Dr. Stoliczka (who identified nummulitic rocks in no other position), and the significance of the tertiary rocks in the history of the mountains is so great, that special interest attaches to observations on this formation.

Gneiss of two ages.—It was fully shewn by Dr. Stoliczka that the metamorphic rocks of the Himalayas are extensively formed of converted palæozoic formations, in continuous relation with unaltered rocks of the same period. The whole of the gneissic axis in Ladák is considered to be so constituted. Elsewhere, unaltered lower palæozoic strata of great thickness are found in abrupt contact, at their base, with gneissic rocks. Two sections of this kind are recorded; both are in the main

Himalayan range, and on the confines of the area described as the Lower Himalayas. The descriptions of the contact are not very precise, but there can be little doubt that the slates were deposited upon a floor of gneiss. In Hundes General Strachey describes and figures some 2,000 feet of infra-silurian azoic slates overlying the crystalline schists in immediate, parallel succession, with a band of coarse conglomerate at or near the junction.[1] The granite of the adjoining axis of intrusion penetrates these slates for a short distance, without producing any great alteration. In the corresponding section described by Dr. Stoliczka on the Bhábeh pass, at the south-east corner of the Zánskár basin in Spiti, a similar relation was observed. The actual contact was concealed by snow; but the lower rocks maintained their gneissic character to the top, and the nearest outcrops to them were of grey slates and sandstones, the lowest beds of a long series of lower silurian strata, quite unaffected by crystalline metamorphism. The latter are probably the same as the infra-silurian beds of Hundes. The dip is somewhat higher in the gneiss than in the slates, suggesting some unconformity or faulting at the contact; but this is not certain, as the observations were some distance apart. Transitional metamorphism is, however, out of the question.

The central gneiss.—We thus have an important fact established, that of an older and a newer gneiss, the difference in age between them being necessarily very great; so that the distinction of the two is a point of much importance in the geology of the mountain region. It was, no doubt, partly to mark this distinction of age, that Dr. Stoliczka gave the name *central* to the gneiss of the main Himalayan axis. The term is certainly ambiguous, and we have already (p. 597) pointed out one important correction in the extension given to it by Dr. Stoliczka; but it may as well be retained, not in the sense of *axial*, but simply as denoting the fundamental formation of the Himalayan rock-series.

Mineral character.—It is unfortunate that so important a distinction depends for detection upon such uncertain criterions as the mineral constitution of metamorphic rocks, and characters so generally obscured as those of contact-relations. The central gneiss is normally composed of white quartz with white felspar (orthoclase or albite), which often forms large crystals, in the more massive varieties of the rock; and the basic mineral is mica (biotite or muscovite), often abundant in the more schistose varieties. The rock of the Ladák gneissic axis is, on the contrary, chiefly syenitic. This cannot, however, be taken as a sure criterion; for elsewhere the silurian slates are found converted into ordinary gneiss.

[1] Q. J. G. S., VII, p. 302.

Stratigraphical relation.—The stratigraphical relation is also of most uncertain application. It is evident that if a later metamorphism had converted the slates of the Niti or the Bhábeh sections, where the two series are in parallel succession, into gneissic schists, the great distinction betrayed by the actual relations (perhaps the greatest in the whole sequence of formations) would have been altogether obscured, and the whole would appear as one continuous metamorphic series. This is precisely the difficulty encountered in attempting to follow out the central gneiss to the north-west, in immediate continuation of the main Himalayan axis; and the same impediment would of course render it still more difficult to detect the older gneiss in a detached area, surrounded by a later gneiss, as in the Ladák axis, or elsewhere. Even along the south boundary of the central gneiss, in the Lower Himalayan area, where there is great unconformity between the gneiss and the slate series (as that unconformity does not involve oblique discordance of stratification), it has been a matter of great difficulty to detect the distribution of the two series, and almost impossible to delineate their separation with any accuracy; the originally highly contrasting conditions of the rocks having been so disguised by the subsequent metamorphism of the newer series, especially near the contact of the two.

Relations defined only in the middle Himalayas.—The very striking contrast of the relations between the central gneiss and the slate series, on the north and on the south, would be a remarkable fact, if it should be confirmed by more extended observations that, as is believed, the two slate series are identical. On the north there is quasi-conformity of superposition, while on the south, as we have seen (p. 601), the newer series overlaps and abuts against denuded masses of the older.[1] From this latter relation it was shewn that the central gneiss must have formed a primitive ridge, to some extent corresponding in position with the Lower Himalayan area. In spite of the contrasting stratigraphy, the northern sections confirm this impression, in that they shew, what was not demonstrable on the south, however apparently probable, that the gneiss underwent its metamorphism in pre-silurian times; and further, it can so far be stated that the evidence for this condition is limited to the confines of the Lower Himalayan area, or a middle Himalayan position with reference to the whole mountain range; everywhere else, in Zánskár, Pángi, and the Pir Panjál, the slates become schistose, and are more or less transitional with the underlying gneiss; or, in other words, the slates along the

[1] It should be recollected that the nearest outcrops exhibiting this contrast are 30 miles apart.

northern border of the Lower Himalayan area have not been subjected to the metamorphic action which they have undergone more or less generally in other parts of the mountains: a fact that would be most naturally explained by these slates never having been so depressed, or subjected to so great crushing, whereby the silurian rocks of the Ladák axis and elsewhere were converted into gneiss. Thus, from the side of the Central Himalayas, in the north, we find confirmation of the evidence brought forward from the tertiary rocks on the south, and from the rock-structure of the Lower Himalayas themselves, that this latter area holds a peculiar, and more or less neutral or independent, position in the Himalayan system.

Although not fully identified out of the Lower Himalayan area, nothing is more likely than that the central gneiss should occur elsewhere; and it has been recognised with much probability in several positions in the divided north-western ranges on the continuation of the main range. Dr. Stoliczka thought he recognised the same rock well to the north of the main range near Changrizing, east of the Pára river, at the base of the great Purgial mountain, which separates the basin of Zánskár from that of Hundes.

The granitic axis.—There is no more unique or debatable feature in the Himalayas than the granitic axis, so persistent along the main range. To the east in Sikkim, and in the north-west, from the frontier of Nepál to Kulu, wherever examined, coarse white granite has been found in profusion along the line of peaks, near the present edge of the sedimentary basin of Tibet. It occurs in veins and dykes of every size, sometimes forming the massive core, up to the summit, of the highest mountains.

The width of the band of intrusion seldom exceeds 25 miles, and is generally much less. The rock dies out completely to the west, being only very feebly represented at the Báralácha pass, the most distant point at which it has been observed in the ranges beyond the Lower Himalayan area, with which again this peculiar feature is nearly coterminous.

This granite is pre-eminently the axial rock of the main Himalayan range, as a geographical feature; and this fact, perhaps, was partly the reason why the name "central" was given to the gneiss in which it occurs, with the implied suggestion that this gneiss had been upraised with the granite; for the contiguous gneiss to the south was regarded by Dr. Stoliczka as distinct. This view has, however, been shewn to be untenable (p. 597); and it is very open to question whether, in any proper geological sense, this line of eruptive rock can be considered an axis

(*locus*) of elevation. The supposition would be incompatible with the inferences already drawn from the circumstances of the sedimentary rocks on both sides of the central gneiss of the Lower Himalayas, shewing absolutely (if correct) that the slate series had never been continuous across that area. It is more likely that the granite marks a marginal line of irruption, with reference to the main area of deposition from which the Central Asian plateau was to arise. From general considerations on the drainage system it will be suggested that the crest of the Himalayan elevation lay far to the north of the present main range. General Strachey describes the granite as penetrating the slates, and the same authority is quoted by Dr. Stoliczka[1] for its reaching the secondary formations. It can scarcely be of later date.

Terminal extensions of the central gneiss.—The distinction of middle and terminal characters is nowhere more marked than in the main Himalayan range, which may, in fact, as a geological feature, be said to end with the Lower Himalayan area. Beyond this, to the north-west, there are three independent ranges with gneissic axes, all connected with the central gneiss, and each having some pretension to be considered the continuation of the main range of the middle Himalayas.

The Zanskar gneissic range.—Immediately north of the Sutlej, and west of the Bhábeh section described by Dr. Stoliczka, there is a great nucleus, or stratigraphical node, of high mountains, ranging to 21,772 feet in elevation, in Waziri Rupi, a district of Kulu. The mass lies for the most part to the north of the prolongation of the main chain. In fact, from the Sutlej, at about the Bhábeh pass, there is a rather abrupt change of about 25° in the strike of the Central Himalayan axes, on opposite sides of the Purgial transverse ridge. The strike of the Hundes basin, and of the main gneissic range south of it, is about west-35°-north; while that of the Zánskár basin, and of the gneissic range outside it, is west-60°-north. The Zoji-La from Kashmir, and the Báralácha from Láhul, are the best known passes in this latter range; and the name of the latter pass has been sometimes applied to the range itself; but it is better to use a term of greater original extension, such as that of the central district of Zánskár. Several of the peaks range above 20,000 feet in elevation.

For many reasons, geological as well as geographical, the Zánskár range has a right to be considered the principal continuation of the Himalayan chain. In its centre, south-west of Zánskár, for a width of nearly 50 miles, it is formed entirely of gneiss; but this rock rapidly contracts to the north-west, and dies out altogether before reaching the Zoji-La, where the sedimentary formations roll over from Tibet into

[1] Mem. G. S. I., Vol. V, p. 12.

Kashmir, and form the mountains on the north side of the valley, at a considerably lower elevation than the gneiss-formed peaks of the range in Zánskár. Here, then, we have a complete terminal occultation of the gneissic axis, in the principal north-western representative of the Himalayan range.[1] The width of the gneiss contracts also very much on the south-east: Dr. Stoliczka observed a band, only 6 miles wide, of what he took to be the central gneiss, low on the south side of the Báralácha pass. It will, however, be shewn that the gneiss of Zánskár is, to some extent at least, a newer rock, formed of converted palæozoic strata.

The Pir Panjal gneissic chain.—If the question of representative ranges were to be settled by the continuous line of greatest elevation, the Zánskár range would have to cede its claim; for the col or gap (the Kunzum pass, on slates, at 14,931 feet), connecting it with the gneissic mass of Rupi, is lower than the Rotáng pass (on gneiss, at 15,206 feet), dividing the mountains of Rupi from those of Bara-Bhagál and Barmaur, which range to above 20,000 feet. It is still unsettled whether the slates of the Kunzum pass are not continuous with those immediately north of the Hamta and Rotáng passes, so as to cut off the gneissic mass of Zánskár. Dr. Stoliczka notes also "the characteristic of albite granite in the gneiss of the Hamta pass."

This Rotáng ridge at the head of the Kulu, or upper Biás, valley is certainly the most direct continuation of the mountains of Rupi; and on this line we find the greatest prolongation of gneissic rock, through Barmaur, Chamba, Badrawáh, and Kistwár, to the Pir Panjál, bounding the Kashmir valley on the south-west. The crest of this chain is more irregular than those we have hitherto spoken of, and this irregularity has always caused a difficulty in finding a name for it. It is perhaps best to extend the well-known name of Pir Panjál to the whole of it. Even in the Pir Panjál proper, the ridge is very irregular, and the gneiss is not continuous throughout; but in this broken fashion the rock continues across the Jhelum to beyond Kashmir, where its mode of termination in the Kishenganga valley is not known; but it probably does terminate there.

[1] To the great disappointment of geologists, all mention of the rocks seems to have been carefully excluded by that accomplished observer Mr. Drew from his most interesting work on the Jummoo and Kashmir Territories. One of the very few remarks that have escaped him records (p. 378) the occurrence of mountains of grey granite on each side of Stakpi La defile, and something less than 2,000 feet above it, between the Burzil branch of the Kishenganga valley and the head waters of the Shingo river. The locality would be nearly on the prolongation of the Zánskár axis, but it probably belongs to a local focus of disturbance in Little Tibet.

In this chain also, according to the few observations on record, the relation of the gneiss to the slates is not of so decided a character as in the Lower Himalayan region. There is generally more or less of transition, and it is difficult to make sure whether we have to deal with the older or the newer gneiss. The abrupt manner in which the semi-detached gneissic masses are intercepted by schists and slates is especially hard to reconcile with other structural features of the sections, as will be indicated in connection with the slate series; but the arrangement of these quasi-continuous masses, independent of an approximately axial position—and there are some, such as the Kund Kaplás mountain in Badrawáh, which cannot pretend to belong to the Pir Panjál chain—is suggestive that the relations of the slates to the gneiss here may be the result, in a minor degree, of an original relation like that described on the south side of the Lower Himalayas in the Simla region, where the slate series was shewn to have been deposited amongst steeply eroded masses of the central gneiss (p. 605).

There is, however, one remarkable observation by Mr. Lydekker[1] in the slates of the Pángi basin, in the upper Chináb valley, separating the Zánskár range from the almost equally high mountains of the Pir Panjál in Chamba, shewing that at the time of the deposition of these slates the central gneiss was undergoing extensive erosion at no great distance. In the midst of the black slates, throughout a thickness of some 2,000 feet, large blocks of granitoid gneiss, either angular or water-worn, are scattered in great numbers. They are well seen about the village of Salgraun (25 miles above Kilár). Some were measured as much as three and a half feet in diameter; and being embedded in fine slate, it seems necessary to suppose that they were in some manner erratics, *i. e.*, transported by some form of flotation or suspension, distinct from the ordinary denuding agencies of water and gravitation only.

The Dhauladhar gneissic range.—There is one other gneissic ridge that might be considered the legitimate representative of the Himalayan axis proper, as being most nearly on its prolongation, in its normal direction. The Dhauladhár is remarkably well defined as a geological axis, although at the very edge of the mountain area, overhanging the tertiary zone in the Kángra valley, and separating this zone from the basin of slates in the upper Rávi valley, which, again, divides the Dhauladhár from the Pir Panjál range in Barmaur. The Kulu valley, which is the upper valley of the Biás, running due south from the Rotáng pass, completely cuts off the Dhauladhár from direct continuity with the mountains of Rupi; but the connexion is maintained at a very high level, from

[1] Rec. G. S. I., XI, p. 54.

the Rotáng pass through the mountains of Bara Baghál, separating the head waters of the Biás and the Rávi. There seems little doubt that the gneiss of the Dhauladhár is to some extent, if not altogether, the central gneiss; but it ends completely and abruptly at Dalhousie, where the Rávi turns round it, at right angles to its course within the mountains. This is a conspicuous instance of the feature already mentioned as so difficult of explanation, and upon which some detailed observations are very much needed.

The newer gneiss.—In preceding paragraphs frequent mention has been made of the newer gneiss; of its special (syenitic) mineral characters where the lower palæozoic formations have been metamorphosed on a large scale, as in the Ladák axis, and of its more ordinary condition where mineralised in connexion with the old gneiss in its extensions to the north-west. Any further mention of the newer gneiss will be made in tracing the general distribution of the palæozoic rocks themselves.

The chief sedimentary basins.—The skeleton of the mountain structure delineated in the foregoing paragraphs, shewing the position and nature of the gneissic axes, will help to elucidate the distribution of the fossiliferous formations, and will suggest at once the convenience of dividing the description according to the great areas, more or less separated, in which these rocks are now found: the two central basins of Zánskár and Hundes or Ngári-Khorsum; the northern basin of the Kárákoram; and the southern area of Kashmir and Pángi.

In speaking of these areas as basins of sedimentary rocks, we do not, of course, mean basins of deposition, but simply stratigraphical basins. They are certainly now basins of disturbance, great synclinal troughs; but it is a leading point of inquiry,—to what extent in any of the successive formations, if at all, the areas of deposition corresponded with these areas of present relative depression of the rocks? The available observations are much too cursory and scattered to support a definite opinion upon this point; but if we might extend to this ground the inference arrived at in the other Himalayan regions, that the palæozoic rocks had undergone no contortion prior to the eocene period, we could not look for much agreement in detail between the actual results of disturbance and the original distribution of the pre-tertiary sedimentary series. Whatever may have been the circumstances which resulted in the striking discrepancy between the rock-series of the Central and the Southern Himalayan areas, whereby all the secondary formations, or at least all the middle and upper groups of that period, were excluded or removed from the southern area, it might seem fair to suppose that the great contortions and dislocations affecting the southern region were more or less of syn-

chronous origin with the similar and connected features in the adjoining area; and, therefore, that the great axes of flexure which now define the rock-basins of Tibet are of post-eocene origin. The very marked approximate conformity exhibited throughout the whole sedimentary series up to the cretaceous deposits, as represented in the sections of the Zánskár basin figured by Stoliczka, and the certainty that at the close of the cretaceous period some of the highest summits of Tibet were at the sea-level, would seem to support the view, that in this region also the beginning of special Himalayan disturbance was posterior to the eocene period.

We must, however, beware of inferential assumptions, however plausible. Enough has been seen in the Sub-Himalayan ground to warn us against placing much reliance upon conformity or unconformity, within very close proximity, in these mountain sections; and the most marked stratigraphical feature of Tibet—the complete severance of continuity between the eocene and the cretaceous deposits—implies great changes in the intervening time, and has a direct bearing upon the point at issue; only we have no observations as to the full or special meaning of this feature. Eocene deposits of great thickness occupy a long trough in the silurian gneiss of the Ladák axis. No one has suggested that they were let down into this position by faulting; so there must have been immense pre-tertiary denudation, with a corresponding rise of the Himalayan area. It is just possible that the original relation in Tibet may have been the same as that already shewn for the nummulitic beds in the Simla region, where they were laid down on deeply eroded, but as yet uncontorted, palæozoic rocks. The fact that the palæozoics of Tibet had been previously converted into gneiss would not absolutely preclude this condition (for the central gneiss is the least disturbed of all the Himalayan formations), although certainly rendering it far from probable.

The settlement of this question—the original relation of the nummulitic formation in Tibet—is a point of extreme interest in Himalayan geology. If it should be proved that that relation was the same as in the Lower Himalayan area—that the immense pre-tertiary denudation of the Central Himalayan region had taken place previous to any great contortion of the strata there—we should have something like a demonstration of the DeBeaumont theory of mountain formation: that the first stage in the process is of the nature of a great warp or deformation of the earth's crust, the collapse (*écrasement*) of which state of tension results in the flexures and dislocations which characterise every region of true mountains.[1]

[1] DeBeaumont's theory of mountain formation is so commonly identified with his final speculations upon the question of direction, that it is necessary to point out that his preliminary discussion of the conditions is independent of that elaborate development.

It has been suggested elsewhere[1] that much of the contortion of the later tertiary rocks of the Sub-Himalayan zone may have been due to a reflex action, the protracted adjustment of equilibrium after the great mountain features had been fully developed.

The formations of the Zanskar area.—Dr. Stoliczka's first work in Tibet (the only exploration of which he published any detailed observations[2]) was confined to the south-east end of the Zánskár area, in the Spiti and Pára valleys, and through Rupshu (or Rukshu) to the Indus. On his second trip he made several traverses of a much larger area, up to the north-west termination of the basin at Kargil; but only brief route-notes were published.[3] The length of the area is 200 miles, with a maximum width of 50 miles in Zánskár. The following detailed characters of the rocks, and for the most part the fossils also, are taken from the former ground; they will serve for general comparison. The names also are taken from localities in Spiti and Rupshu, where the several formations are well exposed. No groups were added from the examination of the larger area to the north-west.

FOSSILIFEROUS SERIES OF THE ZANSKAR AREA.

MESOZOIC:

(*n*) CHIKKIM SHALES (*Cretaceous*).—Dark grey, marly, earthy shales. Thickness, 200 feet. No fossils; considered to be closely related to the limestone.

(*m*) CHIKKIM LIMESTONE (*Cretaceous*).—White, or grey on fresh fracture: when somewhat earthy it gives a strong bituminous odour when struck. Thickness, 600 feet; parallel to *l*.

Rudistes (fragments).
Nodosaria, 2 sp.
Dentalina (*annulata ?*).
Rotalia, sp.
Textilaria, 2 sp.
Haplophragmium, sp.
Cristellaria, sp.

(*l*) GIEUMAL SANDSTONE (*Upper jurassic*).—Light yellowish, silicious; darker and calcareous, fossiliferous; sometimes a loose grit, and even coarsely conglomeratic. Thickness, 600 feet; conformable to and interstratified with *k*.

Opis, sp.
Anatina spitiensis.
A. sp. nov.
Pecten bifrons.
Amusium demissum.
Lima, sp.
Mytilus mytiloidea.
Avicula echinata.
Gyphæa, sp.
Ostrea, sp., near *O. gregaria*.
O. sp., near *O. sowerbii*.

[1] Mem. G. S. I., III, Pt. 2, p. 174; and Q. J. G. S., XXIV, p. 48.
[2] Mem. G. S. I., V, 1865, pp. 1–154.
[3] Mem. G. S. I., V, 1866, pp. 337–354.

(*k*) SPITI SHALES (*Upper jurassic*).—Black, crumbling shale, full of calcareous concretions, each generally containing a fossil. Thickness, 300 to 500 feet; in Spiti they rest conformably on *g*, the lower Tagling limestone.

Belemnites canaliculatus.	*Astarte unilateralis.*
B. clavatus.	*A. major.*
Anisoceras gerardianum.	*A. spitiensis.*
Ammonites acucinctus.	*A. hiemalis.*
A. strigilis.	*Trigonia costata.*
A. macrocephalus.[1]	*Cyprina trigonalis.*
A. octagonus.	*Nucula cuneiformis.*
A. hyphasis.	*N.* sp.
A. parkinsoni.	*Arca* (*Macrodon*) *egertonianum,* Pl. XII, fig. 14.
A. theodorii.	*Inoceramus hookeri.*
A. sabineanus.	*Lima*, sp., near *L. rigida.*
A. spitiensis.	*Aucella blanfordiana.*
A. curvicosta.	*A. leguminosa*, Pl. XII, fig. 15.
A. braikenridgii.	*Amusium* (conf. *Pecten stolidus*).
A. nivalis.	*Pecten lens.*
A. liparus.	*Ostrea*, sp.
A. triplicatus.	*Rhynconella varians.*
A. biplex.	*Terebratula* sp.
A. alatus.	*Salenia ?* sp.
Pleurotomaria, 2 sp.	
Homomya tibetica.	

(*i*) SHALY SLATES (*Jurassic*).—Brown or black; full of broken shells. Thickness, 50 feet; very local; probably belong to *k*.

Belemnites, sp.	*Posidonomya ornata.*

(*h*) UPPER TAGLING (*Lias*).—Dark, earthy, bituminous; only described north of Spiti. Thickness, nearly 1,000 feet; difficult to distinguish from *g*.

Belemnites, sp.	*Trochus epulus.*
Ammonites (conf. *macrocephalus*).	*T. attenuatus.*
Nerinea (conf. *N. goodhalii*).	*Chemnitzia undulata.*
Acteonina (conf. *A. cincta*).	*Neritopsis* (conf. *N. elegantissima*).
Eucyclus (*Amberleya*), sp.	*Modiola*, sp. (resembling *Mytilus subreniformis*).
Trochus latilabrus.	*Terebratula sinemuriensis.*

g) TAGLING LIMESTONE (*Lower Lias or Rhætic*).—Dark grey, brown or black, sandy or earthy, often oolitic and bituminous, sometimes a shell-limestone; weathers light brown, rusty. Thickness, more than 1,000 feet; locally unconformable on *e*.

Belemnites budhaicus.	*Nerinea*, sp. (near *N. goodhalii*).
B. bisulcutus.	*Chemnitzia* (conf. *C. coarctata*).
B. tibeticus.	*C.*, sp. (near *C. phidias*).
Ammonites (conf. *A. germanii*).	*Natica* (conf. *N. pelops*).
A., sp. (conf. *A. macrocephalus*).	*Nerita*, sp., nov.
	Dentalium, sp. (near *D. giganteum*).

[1] According to Dr. Waagen, Palæontologia Indica, Ser. IX, 3, p. 237, foot-note, this and several other species are not identical with the European fossil forms to which they were referred by Dr. Stoliczka.

Arca (*Macrodon*), sp. (apparently *A. lycetti*).
Gervillia, sp. (near *G. olifex*).
Avicula inæquivalvis.
A. punctata.
Lima densicostata.
Pecten (conf. *P. palosus*).
P. moniliger.
P. sabal.
P. bifrons.
P. valoniensis.
Amusium, sp.
Ostrea (conf. *O. acuminata*).
O. (conf. *O. anomala*).
Rhynconella obtusifrons.
R. pedata.
R. fissicostata.
R. austriaca.
R. variabilis.
R. ringens.
Terebratula gregaria.
T. pyriformis.
T. punctata.
T. (*Waldheimia*) *schafhæutli.*

(*f*) Pára limestone (*Rhætic or Upper Trias*).—Black, dolomitic, strongly bituminous, often earthy. Thickness, 700 feet; only found on north side of Spiti.

Dicerocardium himalayense, Pl. II, fig 7.
Megalodon triqueter, Pl. II, fig. 8.

(*e*) Liláng series[1] (*Upper or Middle Trias*).—Dark limestone, calcareous slates and shales; limestone compact or finely oolitic; lower beds quasi-concretionary. Thickness, 1,000 to 2,000 feet; locally unconformable on *d*.

Orthoceras, sp.
O. salinarium.
O. latiseptum.
O. dubium.
Nautilus spitiensis.
Clydonites oldhamianus, Pl. II, fig. 4.
C. hauerinus.
Ammonites floridus, Pl. II, fig. 1.
A. jollyanus.
A. khanikofi.
A. gaytani.
A. diffissus, Pl. II, fig. 3.
A. ausseanus.
A. gerardi.
A. medleyanus.
A. studeri.
A. thuillieri, Pl. II, fig. 2.
A. malletianus.
A. batteni.
Pleurotomaria (conf. *P. buchi*).
P. sterilis.
Discohelix, sp.
Myoconcha lombardica.
Lima (conf. *L. ramsaueri*).
L., sp., nov.
Monotis salinaria, Pl. II, fig. 6.
Halobia lommeli, Pl. II, fig. 5.
Waldheimia stoppanii.
Athyris strohmeyeri.
A. deslongchampsi.
Rhynconella mutabilis.
R. theobaldiana.
R. salteriana.
R. retrocita var. *augusta.*
Spirifer, sp. n.
S. (*Spiriferina*) (conf. *S. fragilis*).
S. (*Spiriferina*) *stracheyi*, Pl. II, fig. 9.
S. (*Spiriferina*) *lilangensis.*
S. spitiensis.
Encrinus cassianus.

[1] The following triassic and rhætic fossils are figured on Plate II:—

Fig. 1. *Ammonites floridus* ½.
„ 2. *A.* (*Ceratites*) *thuillieri* ½.
„ 3. *A. diffisus.*
„ 4. *Clydonites oldhamianus.*
„ 5. *Halobia lommeli.*
Fig. 6. *Monotis salinaria* ½.
„ 7. *Dicerocardium himalayense* ⅓.
„ 8. *Megalodon triqueter* ½.
„ 9. *Spirifer stracheyi.*

PALÆOZOIC:

(*d*) KULING SERIES (*Carboniferous*).—Pale quartzites (fossiliferous) generally at base, but alternating with brown shales; the latter are often carbonaceous and calcareous, passing into dark limestone. Thickness, 100 to 400 feet; junction with (*e*) conformable, obscure.

Orthoceras, sp.	*P. semireticulatus*, Pl. I, fig. 8.
Aviculopecten, sp.	*P. longispinus.*
Cardiomorpha, sp.	*Spirifer moosakhailensis*, Pl. I, fig. 2.
Avicula, sp.	*S. keilhavii*, Pl. I, fig. 1.
Productus purdoni, Pl. I, fig. 10.	*S. tibeticus.*
	S. altivagus.

(*e*) MUTH SERIES (*Upper Silurian*)—

White quartzite, often speckled; no fossils. Thickness, 200 to 300 feet.

2. Pale sandy and silicious limestone, purer beds dark; weathering brown; fossiliferous. Thickness, 300 to 400 feet.
1. Purple sandstone, slaty partings; conglomeratic; no fossils. Thickness, 500 to 600 feet; conformable to *b*, slightly alternating.

Tentaculites, sp.	*Orthis*, sp. (near *O. tibetica*).
Strophomena, sp.	*O.*, sp. (conf. *O. resupinata*).
Orthis, sp. (near *O. thakil*, var. *striatocostata*, and var. *convexa*).	Crinoid stems.
Orthis, sp. (near *O. compta*).	*Cyathophyllum*, 2 sp.
	Syringopora, sp.

(*b*) BHÁBEH SERIES (*Lower Silurian*)—

3. Greenish and bluish sandstones sometimes micaceous, often laminated; also thickly bedded, occasional slaty and calcareous beds, fossiliferous. Thickness not stated, but represented in the section as equal to 2 or 1.
2. Grey, white and pinkish, speckled sandstone or quartzite, with occasional calcareous beds, dolomitic and cavernous (Rauchwake), fossiliferous. Thickness not stated; figured as much as No. 1.
1. Bluish and greenish grey slates (some micaceous) and sandstones; no fossils. Thickness, 3,000 feet.

Orthis, sp.?	*Chætetes yak.*

Palæozoic series.—A large part of Stoliczka's Memoir is given to the description and discussion of the fossils, a complete list of which has been given above; besides this there is not much matter for discussion, and it would be too tedious without a full-scale map to trace the formations severally wherever they have been observed. It will be more suitable here to take them up in series, and to indicate the conditions they exhibit at different points of the area. This sketch possesses the advantage, so rarely experienced in Indian formations, that the stratigraphical identifications were made upon the basis of palæontological evidence. The palæozoic series, as given in the above list, is, of course, only illustrative, not in any sense a standard; even here, in several of the groups,

much variation is noticed. The observations were taken at the south-eastern extremity, where the Zánskár basin approaches nearest to the Lower Himalayan area, and where the strata exhibit a minimum of alteration. It is only in this portion of the area, within the Spiti basin, which drains into the Sutlej, and has undergone the greatest erosion, that the upper palæozoic rocks are freely exposed, away from the edge of the basin. In Spiti the Kuling series is very frequently found at the bottom of the deepest valleys, underlying the secondary formations of the adjacent mountains. In the more elevated ground of Zánskár it has been noticed only in a few localities in this position, as in the Tzárap valley. There is no mention of the silurian rocks being exposed, except along the marginal outcrops.

South-west boundary.—To the north-west of Spiti the palæozoic series is still recognisable at the Báralácha pass. The rocks immediately above the central gneiss are like those of the Bhábeh section; and fossils were found at a low horizon in the silurians. The next section is on the Zánskár river, near Padam, where the boundary between the two series is not fixed, within broad limits; and from this to the westward, along the flank of the Zánskár ridge to Suru (Sooroo), near the north-west end of the Zánskár basin, the metamorphism increases, and the whole palæozoic series becomes gradually disguised. On the Suru section the metamorphics of the Zánskár range extend northwards to Sangra, near Kartse (Kurtse), where they are largely hornblendic, and supposed to be upper silurian. The chloritic quartzites north of this are considered to be carboniferous, and they are in contact with the syenitic rocks of Kargil, against which the sedimentary basin terminates on the north-west.

South-east boundary.—Proceeding north-eastwards from the Bhábeh pass, we follow the south-east end of the Zánskár basin, as stopped out against the central gneiss of Purgial. The details of this feature have not been observed, but, as seen in the section of the Spiti river, only 25 miles from Muth, some important changes are recorded. Fossils were found far down in the series, near Kuri and Shálkar. The gneiss is overlaid by dark, thin-bedded slates and sandstones, but apparently not immediately; for the chief contrast between this and the Bhábeh section is stated to be that the lower strata on the Spiti are more altered, in a few places truly metamorphic, and that the higher beds are more slaty. But the most peculiar difference is the appearance of interbedded greenstone throughout the whole series, from the gneiss up to the carboniferous rocks near Po (on the Spiti river). The thickness of the deposits seems to be greater here, especially of the carboniferous series, if all the brown shales at the top of the section belong to this formation.

The disturbance is not excessive; it is locally described as if the schists had been upheaved in the form of a dome.

The Rupshu metamorphics.—The next section is 40 miles to the north, in the upper valley of the Pára river, where the conditions of the north-east boundary are fully established. The first effects of metamorphism are noticed in the triassic rocks; but the greenish quartzites and slates beneath them are still recognisable as of the Kuling series, and have yielded carboniferous fossils. Beneath the quartzites and slates come chloritic and mica-schists, doubtless representative, if the observations be correct, of the silurian rocks, but differing entirely from them in facies. The south-westerly dip continues remarkably constant for 24 miles across a vast thickness of these metamorphic strata, a third of which would amply represent the known thickness of the lower palæozoic series; so that, unless there are undetected repetitions, there must be either great expansion of these formations, or we have here also an unknown thickness of the old gneiss. This would seem by no means improbable; for below some 10,000 feet of the mica-schists, at about the middle of the Moríri lake, there is a strong band of granitoid rock, not unlike the central gneiss. It is underlaid by a great series of thin quartzose schists, locally gneissose, below which, at the Kiágar lake, is another mass of gneiss, characterised by large imperfect crystals of felspar and much tourmaline. This gneiss is thin-bedded, and passes down again into quartzose schists. At last, within six miles of the Indus, there is a reverse (north-east) dip in these beds, and so they abut against (are traversed by) a great mass of basic igneous rock, forming a line of irruption along the Indus.

A passing reflection may be recorded on the absence, in the infra-carboniferous rocks of Rupshú, of bedded greenstone, so abundant throughout the silurians of the Spiti valley. The fact would be enough to awaken doubt whether any of these metamorphics can be converted silurians; save that the total absence of those same rocks in the Bhábeh section rather suggests that they are not truly contemporaneous in the Spiti ground.

The Rupshu metamorphics continue to the north-west, with a constantly diminishing width, the massive gneiss being still in force at Gya (36 miles south-south-east of Leh), where it is described as having a large proportion of white quartz, but the mica is occasionally replaced by diallage. This is close to the axis of eruptive rock.

North boundary with tertiary rocks.—Not far to the west the Rupshu metamorphics must die out altogether; for at the Zalung Karpo pass, 15 miles west of Gya, carbonaceous slates and limestones underlie the Liláng (triassic) limestone, and are the only rocks seen from this

all down the Marcha valley to Skiu, near the Zánskár river, where carbonaceous limestone, full of crinoid stems, and presumably carboniferous, is in close proximity to the nummulitics. Silurian rocks were not distinguished in this section, but Stoliczka considers that they are probably present. The eruptive rock is not noticed in the section at Skiu. The next section is 30 miles west of the Zánskár river, on the road from Drás to Leh. Here the slates, green and red shales and sandstones, between the serpentine of the Indus and Lámayúru, are recognised as of the Bhábeh series. They are contorted, with a prevailing south-west high dip, and are overlaid by a few hundred feet of carbonaceous shales, which are spoken of as of the Muth series, and also as carboniferous.[1] The rocks are spoken of as highly metamorphic-looking, and at the same time as not easily distinguished locally from the adjoining tertiary rocks. Farther on, west of Kharbu, the tertiary rocks, both sedimentary or igneous, encroach still more; and about Shargol they are in obscure contact with the triassic limestone. The next mention of the palæozoic series is at 16 miles to the west, where we have already seen them, much altered, in contact with the syenite of Kargil.

Thus it appears that for about half its length, on the north, the Zánskár basin of palæozoic and secondary rocks is now bounded by tertiary formations. On the north-west these contiguous, but distinct, basins end together against the syenitic mass of Kargil; but to the south-east the tertiary rocks pass continuously into the broad central area of metamorphic rocks, those of Rupshu on the south-west, and those of the Ladák range on the north-east. The latter will be noticed in connexion with the Kárákoram area, where they are described in sequence with the fossiliferous rocks of that basin.

The secondary series.—The series of secondary formations in the Zánskár area, recorded in the list at p. 635 amounts altogether to a thickness of 8,000 to 9,000 feet. From the structural condition of the area, shewing that it is proximately at least a basin of disturbance, the general distribution of the formations may be surmised; and we have already traced a continuous outcrop of the palæozoic rocks round the edge of the basin, except on the north, where the structural symmetry is broken by the contact of an independent and much later basin of tertiary rocks. As there is general conformity throughout the entire sequence of formations, each is principally exposed along the external outcrop of its area, and then along the sides of the deeply eroded river gorges traversing the basin, where all the strata are variously affected

[1] These observations are taken from Stoliczka's notes, in the Scientific Results of the Second Yárkand Mission: Geology, pp. 13, 14: Calcutta, 1878.

by minor undulations and contortions. The great limestones of the Liláng and Tagling groups are the most prominent rocks of the area; while the later formations—upper jurassic and cretaceous—are reduced to comparatively small patches in the centre of the basin, in the hollows of local synclinals or as remnants on the tops of ridges.

On the much more obscure question of the original distribution of these formations, there is very little to be said. It is important to record the few remarks on this point made by the observer himself, from whom these descriptions are taken. In his reflections on his second year's work Dr. Stoliczka remarks (*l. c.*, p. 352): "Referring to the section near Muth, as far as I can see now, I believe that the carboniferous deposits here seem to close a grand geological epoch, and that in the main their deposits filled only the interior of a large basin, which gradually and partially became dry land. The carboniferous rocks now appear sparingly dispersed in consequence of undulating contortions of the entire ground. Towards the west, especially in Kashmir and Little Tibet, the carboniferous rocks are, however, much more developed." On the same page it is written, that "after the close of the triassic group in the North-West Himalayas, great disturbances must have taken place; large tracts of the country were raised, and never more covered by the sea, until partially in comparatively recent periods (eocene), while in other places the regular succession of deposits took place. One of these was evidently the large northern jurassic basin of the Himalayas." Again, a little further (*l. c.*, p. 353): "The jurassic basin, which is so well developed in Spiti, and extends to North Kumaun, continues to retain the same north-western direction, with all the characteristic rock-formations, until it becomes interrupted by the great granitic and syenitic mass of Little Tibet. A partial interruption seems to have taken place after the close of the rhætic deposits; but whether the jurassic basin has been actually and totally interrupted here (that is, south of the Indus), or whether it has been only compelled to continue with its course towards the north or north-west in Gilgit and beyond the Mustágh range, subsequent inquiries must prove."

The particular observations upon which these impressions were based are not indicated; and it must be said that from an independent study of the recorded observations, such inferences could not be made, or even that a different interpretation is suggested. No facts are quoted shewing the great disturbance of the Liláng series independently of the later formations, preparatory to the formation of the jurassic basin. The lower jurassic group, the Tagling limestone, appears in full force, forming the highest summits close to the edge of the basin, both on the north and

south; and the original limitation of the jurassic rocks anywhere near this seems to be purely conjectural. The only instances given, in the Pára and upper Tagling limestones, of interpolation and thickening of strata have no reference to the actual basin; they begin to the north of its centre, and expand towards its present north margin. The only appearance of an original basin, corresponding with the actual one, is in the upper secondary deposits—the Spiti and Chikkim groups; and even for these the case is not very evident. The best case quoted is that at Muth, where the carboniferous (Kuling) group seems to be regularly overlapped by the Liláng beds; but this, like the two cases just mentioned, only points to a southern limitation of the Himalayan deposits. The greatest difficulty in the way of the latter supposition, as a general feature, is the great thickness of the silurians in the Bhábeh section; the only relief to it being the preponderance of sandstone in that position, contrasting with finer deposits elsewhere. On the whole, it is evident that the date of formation of the Zánskár basin is still an open question, within very wide limits.

The tertiary series.—It is in connection with the Zánskár area and Dr. Stoliczka's work that we have to notice the tertiary rocks of the Central Himalayas. Here, as in the Sub-Himalayan zone, their features and relations are of first importance in the mountain history. With the exception of some almost unknown deposits (to be mentioned again), from which the Siwalik fossils brought from the Hundes area must be derived, the tertiaries of Tibet are, so far as known, eocene, or, at least, nummulitic. Dr. Stoliczka describes them as very similar to the corresponding deposits of the Sirmúr area in the Simla region: "soft and partly loose conglomerates, reddish and purple slates and marls, and greenish sandstones, much like those on Dagshai hill and to the north of that station" (*l. c.*, p. 343). From these beds at Rámbag, close to the Indus, near Leh, he procured *Nummulites ramondi* and *N. exponens*. In some of the lowest beds of the same group near Kargil, some fossils found by Mr. Drew are mentioned by Dr. Stoliczka as "very like *Melania*, and bivalves almost unmistakably belonging to *Pholadomya* or *Panopæa*" (*l. c.*, p. 348); and he alludes to the beds again as "a brackish and fresh water deposit."[1] The thickness of these strata here is given as 5,000 feet (*l. c.*, p. 348).

According to Dr. Stoliczka's observations, these rocks extend from Kargil on the west, where they end against the syenitic rocks of Baltistán, continuously along the Indus for more than 200 miles to beyond the eastern limits of his explorations. This long trough is seldom more than 25 miles wide, and from end to end a line of eruptive rock accompanies the eocene strata, generally on the south side, but also in the midst of the

[1] Rec. G. S. I., VII, p. 13.

sedimentary rocks, as at the west end about Páskim. Varieties of the eruptive formation are described as epidotic rock, consisting of crystallised or granular masses of epidote, quartz, and albite; also as diallage rock, serpentine, and gabbro. When Dr. Stoliczka first examined these tertiary rocks in Northern Rupshu, the nummulitics are there so indurated, consisting of green and red sandstones and slates, with a thickness of 3,000 to 4,000 feet, that they were taken to be probably a palæozoic series; the eruptive rock also is in great force, being 15 miles wide at the Hánle river, and upon it Stoliczka remarked: "From their dark colours, these rocks have sometimes been referred to the basalts, but they have certainly nothing to do with these more recent volcanic rocks"[1] (*l. c.*, p. 128).

On the north-east side this long compressed basin of tertiary rocks is bounded throughout by the syenitic metamorphic series of the Ladák axis; on the south-west for half its length it is in contact with the Rupshu metamorphics, which thin out gradually, and are replaced to the north-west by the palæozoic slates of the Zánskár basin; and farther on, the nummulitics reach to the triassic outcrop within that basin. Although Dr. Stoliczka found no trace of nummulitic rocks to the south of this very peculiar and well-defined area, he seems to have accepted without hesitation (*l. c.*, p. 354), as of the same deposits, Dr. Thomson's discovery of nummulitics on the Singhi pass (16,600 feet), on the route between Padam and Leh, in the centre of the Zánskár basin. Without presuming to question the possibility of this occurrence, upon so slight a knowledge of the geology of the region, the obvious importance of this observation suggests an examination of its authenticity.[2]

1 This, of course, refers to the idea, prevalent amongst German geologists until recently, and still held by a large number, that different igneous rocks are characteristic of particular geological epochs. See foot-note, p. 302.

2 Dr. Thomson's record of the rocks on the Singhi La is as follows ("Western Himalayas and Tibet:" 1852, p. 381): "Quartz rock, slate, and limestone alternated during the ascent; and near the summit of the pass the limestone evidently contained organic remains, perhaps coralline; though their traces were not sufficiently distinct to enable me to decide the point." This observation does not at all suggest an outlying high-level remnant of newer rocks, like those of the Indus valley, but of well-indurated strata, forming the mass of the adjoining mountains. The identification of the fossils is recorded at page 176 of the "Description des Animaux Fossiles du Groupe Nummulitique de l'Inde," by MM. D'Archiac and Haime, as follows: "Un calcaire gris bleuâtre, compacte, pétri d'*Alveolina melo*, associée à une nummulite qui paraît être la *N. ramondi*, a été observé en place par le docteur Thomson, dans la chaine même de l'Himalaya, au passage et au col de Singhi La, lorsqu'il se rendait de Zanskar à la vallée de l'Indus." There is nothing to suggest doubt or discrepancy in these records; but so great errors of locality amongst the fossils described in this work have been found out (see note, p. 531), that there is room for doubt, where there is anything to suggest it; and it appears desirable that the occurrence of nummulitic rocks on the Singhi La should be verified.

There are no detailed observations to shew the relation of the Indus nummulitics to the contiguous rocks. The facies of the deposits is that of a local basin; and this seems to be the view taken of them by Dr. Stoliczka, at least at the western end; he says: "I rather presume that these beds have been formed in a kind of narrow bay of the tertiary sea, which covered Northern and Eastern Tibet" (p. 348). In his route-notes on his journey to Yárkand, in the same western area, between Shargol and Kharbu, he describes lumps and patches of the triassic limestone sticking out of the tertiary shales.[1]

It seems at least certain from the condition and position of the eocene rocks of the Indus, that vast denudation, and therefore disturbance (*quoad* elevation), of the Himalayan area had occurred in pre-tertiary times. It remains for future observation to shew how far the special disturbance of the older formations corresponds with that which the eocene rocks themselves have undergone.

[1] Scientific Results of the Second Yárkand Mission: Geology, p. 13: Calcutta, 1878.

CHAPTER XXVII.

EXTRA-PENINSULAR AREA.

CENTRAL (TIBETAN) HIMALAYAS—*continued.*

The Hundes or Ngári-Khorsum area — Stratigraphical series of Niti in Hundes — The tertiary eruptive rocks of Hundes — The sedimentary tertiary rocks of Hundes — The Kárákoram area — The Ladák gneiss — The eastern section of the Kárákoram basin — The Kárákoram section — The Kuenlun range — The Suket pass section — The Yángi pass section — The Pámir section — The Kashmir-Pángi area — Triassic rocks of Kashmir — Carboniferous rocks of Kashmir — Silurian rocks of Kashmir — The Pángi basin — The Pir Panjál Chain — One-sidedness of mountain structure — Post-tertiary and recent formations — Sub-Himalayan high-level gravels — Glacial evidence in Tibet — The Hundes lake-basin — Lingzhíthang and Kuenlun lake-basins — Tso Moríri and other basins — Alluvial deposits of Tibet — The Kashmir basin — The Nepál valley — Other lakes — Drainage lines. SUMMARY.

The Hundes or Ngari-Khorsum area.[1]—Although we cannot refer to actual record of the observations, it is probable that the palæozoic series is continuous from the Zánskár basin into that of the Hundes; it is coloured so on General Strachey's map of the Hundes region, no doubt on good authority. It remains for future observation to shew whether the mesozoic formations of the two areas were originally continuous or not; at present they are separated by the gneissic mass of Purgial, against which the Sutlej turns southwards, and which is now the north-western barrier of the present basin of secondary rocks of the Hundes province. At 180 miles to the south-east of Purgial the great Gurla mountain (25,200 feet high), south of Mánasaraur lake, stands right in the axis of the Hundes basin, and may be taken as its limit on this side; although here, too, there is a band of palæozoic and mesozoic rocks passing partially to the south of it, up to the edge of the area explored. Whether continuously or not, it is fairly established that jurassic rocks occur far to the east on this strike, north of Nepál, characteristic ammonites having been brought by traders from that region. On General Strachey's map the gneissic formations of both Purgial and Gurla are shewn to be intrusively penetrated by granite; so we may accept them provisionally as formed of the central gneiss.

[1] Captain Richard Strachey, on the Geology of part of the Himalaya Mountains and Tibet, Q. J. G. S., 1851, Vol. VII, p. 292.

The general aspect of the Hundes area must be very different from that of Zánskár. With the exception of a few small lake-basins, and occasional alluvial patches in the deep river-valleys, Zánskár is covered by lofty rugged mountains, many rising above 19,000 feet, and holding considerable glaciers. The central area of the Hundes is occupied by a great spread of diluvial deposits forming an extensive plateau, 120 miles in length and from 15 to 60 in breadth, at an elevation of from 14,000 to 16,000 feet. It is intersected by great ravines, that of the Sutlej to the west being nearly 3,000 feet deep.

Stratigraphical series of Niti in Hundes.—The numerous collection of fossils made by General Strachey was described by Messrs. Salter and H. F. Blanford, from whose work[1] the subjoined lists are taken; the petrological characters being collected from General Strachey's paper. In most cases the thicknesses are not estimated :—

FOSSILIFEROUS SERIES OF THE HUNDES AREA.

Hard grits, shales, and limestones ; no fossils found.

Oolitic : Dark crumbling shales with hard nodules (Spiti shales), full of fossils; below them are several thousand feet of various limestones (not examined) underlaid by black limestones and shales, with imperfect fossils.

Belemnites sulcatus.
Ammonites acucinctus.
A. alatus.
A. bifrons.
A. biplex.
A. communis.
A. concavus.
A. eugenii.
A. gerardi.
A. griffithii.
A. guttatus.
A. hookeri.
A. heterophyllus.
A. himalayanus.
A. hyphasis.
A. jubar.
A. medea.
A. nepalensis.
A. octagonus.
A. robustus.
A. scriptus.
A. spitiensis.
A. strigilis.
A. tenuistriatus.
A. torquatus.
A. triplicatus.
A. thouarsensis.
A. umbo.
A. wallichii.
Turritella montium.
Pleurotomaria? sp.
Turbo invitus.
Chemnitzia, sp.
Anatina vaginula.
Myophoria blanfordi.
Cardium truncatum.
Cyprina trigonalis.
Astarte major.
A. unilateralis.
Modiola, sp.
Nucula cuneiformis.
Cucullæa virgata.
C. leionota.
Inoceramus hookeri.
Lima acuta.
L. gigantea.
L. mytiloidea.
Monotis concentricus.

[1] Palæontology of Niti in the Northern Himalayas. Printed for private circulation by General Strachey: Calcutta, 1865.

Avicula echinata.	*O. acuminata.*
A. inæquivalvis.	*Terebratula numismalis.*
Pecten æquivalvis.	*T. carinata.*
P. comatus.	*T. globata.*
P. bifrons.	*Rhynconella variabilis.*
P. monilifer.	*R. concinna.*
P. lens.	*Acrosalenia?*
P. sabal.	*Pentacrinites,* sp.
Ostrea flabelloides.	

Triassic (Upper): Dark-coloured limestone, associated with shales and dark red grits.

Ammonites floridus, Pl. II, fig. 1.	*Natica subglobulosa.*
A. aon.	*Exogyra* sp.
A. winterbottomi.	*Halobia lommeli,* Pl. II, fig. 5.
A. planodiscus.	*Pecten scutella.*
A. diffissus, Pl. II, fig. 3.	*Lima stracheyi.*
A. gaytani.	*Athyris deslongchampsii.*
A. ausseeanus.	*A. strohmeyeri.*
A. blanfordii.	*Waldheimia stoppanii.*
Ceratites jacquemonti.	*Rhynchonella retrocita.*
Orthoceras pulchellum.	*Spirifera oldhami.*
O. salinarium.	*S. stracheyi.*

Carboniferous: The rock not identified *in situ.*

Productus purdoni, Pl. I, fig. 10.	*Athyris roissyi.*
P. flemingii.	*Aviculopecten hyemalis,* Pl. I, fig. 13.
Chonetes vishnu.	

Silurian[1]: *g.* White quartzite; no fossils.

f. Pale flesh-coloured quartzite; no fossils.

e. Dark-red grits, sometimes marly; with Crinoid stems.

d. Earthy slates and concretionary limestones, *Cyrtoceras, Orthoceras, Chætetes.*

c. Flaggy limestones and grits: most of the Trilobites, *Strophomena, Leptæna, Lituites, Ptilodictyon, Cystidea,* and Fucoids.

b. Limestones and slates: the strong-ribbed *Orthis* (*O. thakil*), *Terebratula, Lingula, Bellerophon,* fragments of *Encrinites*

a. Dark, thick-bedded, coralline limestone.

[1] No plate of the Himalayan silurian fossils has been given in the present work for want of specimens to illustrate. But few have been procured by the Geological Survey, and the figures in Mr. Salter's work are not well adapted for reproduction by lithography. Owing to the rarity of silurian fossiliferous rocks in India and the neighbouring countries, illustrations of the fossils are not of much importance.

The total thickness of these groups is estimated at 6,000 feet.

Asaphus emodi.	*Cyrtodonta ? imbricatula.*
Illænus brachyoniscus.	*Lingula kali.*
I. punctulosus.	*L. ancyloides.*
Cheirurus mitis.	*Leptæna himalensis.*
Prosopiscus mimus.	*L. repanda.*
Sphærexochus idiotes.	*L. cratera.*
Lichas tibetanus.	*L. nux.*
Calymene nivalis.	*Strophomena trachealis.*
Tentaculites, sp.	*S. chæmerops.*
Serpulites, sp.	*S. umbrella.*
Nautilus ? involvens.	*S. aranea.*
Cyrtoceras centrifugum.	*S. nubigena.*
Lituites iuliformis.	*S. bisecta.*
Orthoceras striatissimum.	*S. halo.*
O. kemas.	*S. lineatissima.*
Theca lineolata.	*Orthis thakil.*
Bellerophon ganesa.	*O. tibetica.*
Murchisonia himalensis.	*O. compta.*
M. pagoda.	*O. monticula.*
Pleurotomaria turbinata.	*O. uncata.*
Raphistoma emodi.	*Ptilodictya ferrea.*
Trochonema humifusa.	*P. plumula.*
Cyclonema rama.	*Sphærospongia melliflua.*
C. subtersulcata.	*S. inosculans.*
Holopea varicosa.	*Chætetes ? yak.*
H. pumila.	*Heliolites depauperata.*
Ctenodonta sinuosa.	

SLATE SERIES : No fossils found ; coarse slates, grits, and limestones, with coarse conglomerate of rounded quartzose rocks, at base ; 9,000 feet.

METAMORPHICS : Many varieties of mica-schists and gneiss, with beds of highly crystalline limestone and calcareous schists.

From a small collection made by Mr. Hughes, of the Geological Survey, on a trip over the Milam pass, Dr. Waagen has somewhat extended the list of formations in the Hundes basin. The following notes are taken from his paper[1] :—

CRETACEOUS FOSSILS :—*Corbula* cf. *cancellifera ; Astarte ; Pectunculus ; Cucullæa.* The facies of these fossils is considered to be decidedly cretaceous.

JURASSIC FOSSILS :—

Belemnites cf. *kuntkotensis.*	*Ammonites* (*Perisphinctes*), sp. (*triplicatus*, Stol., *non* Sow.)
Ammonites (*Oppelia*) *acucincta.*	*A.* (*P.*) *sabineanus.*
A. (*Perisphinctes*) *frequens.*	*A.* (*P.*) *stanleyi.*

[1] Rec. G. S. I., XI, p. 184.

Ammonites (*Perisphinctes*), sp.	*Aucella blanfordiana.*
A. (*Stephanoceras?*) *wallichii.*	*Au.*, sp., nov.
A. (*Cosmoceras*) *theodori.*	*Pecten*, sp.
A. (*C.*) *octagonus.*	*Rhynchonella*, sp. (*varians*, Blanf., *non* Schloth.)
Aucella leguminosa.	

Triassic fossils :—A *Monotis*, two *Pecten*, and *Rhynchonella austriaca*, are recognised as of an upper triassic horizon. They occurred in a hard, flaggy, dark-grey limestone. Two fragments of *Ammonites* of the *Am. semipartitus* group, in a smooth, dark-grey, hard shale, are considered as probably belonging to the Muschelkalk, and the Bunter is indicated by a red cryptocrystalline limestone containing a Ceratite like one of the Salt Range species.

Permian and carboniferous fossils :—A white limestone full of crinoid-stems yielded—

Terebratula himalayensis.	*Camerophoria*, sp. nov. ?
T. subvescicularis.	*Productus semireticulatus.*
T., sp. nov. ?	*P.*, sp.
Athyris roissyi.	*Bactrynium*, sp.
Spirifer cf. *glaber.*	*Cyathophyllum*, sp.

This fauna is noticed as much resembling that of the lower carboniferous limestone in the Salt Range. A black shale gave a *Rhynchonella*, allied to *Rh. acuminata;* and a dark liver-coloured limestone contained *Spirifer* cf. *striatus; Stringocephalus ?* sp.; *Rhynconella ?* sp.

Silurian fossils :—A white sandstone yielded *Strophomena aranea.*

The crystalline schists (central gneiss) at the edge of the Hundes basin are profusely penetrated by a coarse, white granite, with much schorl and kyanite. All the great peaks of the snowy range occur in this zone. The summits of the highest passes, which average about 18,000 feet in elevation, are in the zone of palæozoic rocks, which rise into peaks some 2 000 feet higher than the passes. A northerly dip is constant throughout the whole stratified series; and no unconformities were detected. General Strachey considers that the south edge of this basin has probably been a sea margin from the remotest ages of the earth's history (*l. c.*, p. 308).

The tertiary eruptive rocks of Hundes.—There can scarcely be a doubt that the igneous rock so conspicuous at various points of the Hundes area is the same as, and probably continuous with, the middle tertiary (or at least post-nummulitic) eruption of the Indus valley in Ladák and Rupshu (p. 643). General Strachey describes a great outburst of this rock, 35 miles wide, "in which are found hypersthene and bronzite, besides syenitic and ordinary greenstones, and various varieties of porphyry," forming the western shores of the Rákas Tál, which is the western companion of the Mánasaraur (Manasarowar) lake; and from here

the trap seems to extend in force to the north-west, on the north side of the Hundes plain. The intrusion is not, however, so restricted to this main line of eruption as it seems to be in Ladák; for General Strachey has mapped several detached protusions of the same rock, notably that forming the Bálch pass, surrounded by jurassic strata. Others appear surrounded by the Hundes plains deposit, and it would seem in the figured section that the trap penetrates, and now overlies, these very new rocks. This error of drawing is sufficiently corrected in General Strachey's text, where, in a paragraph of the summary, it is distinctly stated that the tertiary beds of the plains were deposited upon and contain debris of the eruptive rock. The jurassic strata being the latest known to be affected by the intrusive rock here, this has been taken as a lower limit of age for the eruption, and the supposed tertiary deposits of the plains have given an upper limit of date. The correlation of the rock with that of Ladák reduces the question of its age to much narrower limits, as middle tertiary.

The sedimentary tertiary rocks of Hundes.—The earliest evidence, so far as known, of tertiary rocks in Tibet, came from the Hundes area. In the first quarter of the century, long before the discovery of the Siwalik fossils, fragmentary remains of extinct mammals from beyond the Niti pass were brought to notice. Specimens were even presented to the Geological Society of London about that time by Sir Thomas Colebrooke and Dr. Traill; others were sent to the British Museum. But from that time till now they have received little or no attention, probably on account of their fragmentary condition, and because nothing precise was then known as to their geological position. General Strachey to some extent removed this latter objection (*l. c.*, p. 306), by declaring that these fossils were derived from the great undisturbed diluvial deposits filling the upper valley of the Sutlej to a depth of 3,000 feet, and forming the wide plain of Hundes. He also enumerates some approximate determinations of the specimens he collected himself, made at his request by Mr. Waterhouse: there were—bones of *Hippotherium* (*Hipparion*); of several varieties of horse; of a bovine ruminant; a head allied to goat or sheep; a vertebra of rhinoceros; tooth of elephant (?). The evidence is not sufficient for correlation with any precise horizon; the fauna is, however, an extinct one, and may perhaps be relegated to some place in the great Siwalik series.

General Strachey did not, however, omit to state that none of his specimens were found *in situ*, and that, in spite of every attempt, he could not hear of a definite locality in which any one knew positively that they had been found. His own conviction as to their being derived from the horizontal plain's deposits is based on their general position, supported

by the fact that on many of the specimens there are attached remnants of a fine calcareous conglomerate, exactly identical with beds observed intercalated with the boulder and gravel-beds that constitute the mass of the deposits. This point cannot be much insisted on; for the complete similarity of such rocks in different groups is well known (p. 555). Any shadow of doubt upon the correctness of this inference comes principally from the asserted horizontality of these deposits, whereas the latest Siwalik beds in the Sub-Himalayan zone are locally vertical; and even some doubtfully tertiary deposits in the Kashmir and Nepál valleys (to be mentioned in our brief notice of the Himalayan post-tertiaries) have suffered some disturbance. It should be noticed that the occurrence of a displacement of the Hundes deposits seems to have been contemplated by General Strachey; for he speaks of some similar deposits, to the south of the Niti pass, as having been separated from the general mass by the dislocations that have upheaved the whole country (*l. c.*, p. 308). These discrepancies are noticed with a view to verification by future explorers: it may be that beneath the general mass of undisturbed diluvium forming the Hundes plains, there may occur obscure outcrops of similar deposits, of much older date, that have undergone considerable disturbance. The comparative antiquity of even the most recent beds of the Hundes plain seems to be attested by the existence of ancient moraines upon that plain (*l. c.*, p. 310). These deposits will be referred to again with others of a like nature.

The Karakoram area.—Dr. Stoliczka's observations on this ground were taken under very trying circumstances, while making forced marches at a most unseasonable time of year. His outward route lay by the Pángkong, Chángchenmo, Lingzhíthang, and the Upper Kárakásh valley. His return journey lay more to the west; his last march but one was across the Kárákoram pass.[1]

The Ladak gneiss.—The entire ridge north of the Indus consists of syenitic gneiss of extremely variable composition. The typical rock is a moderately fine-grained syenite, with veins richer in hornblende; some portions contain much schorl. In finer varieties the felspar almost disappears, and the quartz is very scarce, forming a hornblende schist. In places the hornblende disappears, the crystals of felspar increase in size, and with mica (biotite) and quartz form an ordinary gneiss, but inseparable from the syenite, to which it is subordinate. To the north the syenitic gneiss passes into hornblende and chlorite schists, alternating with quartzose schists of great thickness. These rocks extend to the

[1] Rec. G. S. I., VII, pp. 12 and 49; also, Scientific Results of the Second Yárkand Mission: Geology: Calcutta, 1878, pp. 15-20, and 45, 46.

Lunkar-la or Másimik pass. They are intimately connected with a greenish chloritic rock, both thin-bedded and more massive, the latter sometimes distinctly crystalline, containing bronzite, and passing into diallage. These beds are compared to those found about Srinagar, in Kashmir (Mr. Lydekker's silurian trappean group); they occupy the south-west side of the Chángchenmo valley. On the western route similar rocks were traced, by Dr. Bellew, up the Nubra valley to near the foot of the Saser pass. Dr. Stoliczka says: "I think we have to look upon this whole series of schistose and chloritic rocks as the representatives of the silurian formation." The remark seems to include all the rocks of the Ladák range; but this is not certain, for a little further on in the same short paper the Kárákoram area is spoken of as bounded on the north and south by syenitic rocks, including between them the silurian, carboniferous, and triassic formations. The Ladák gneiss is so unlike the description given (by the same observer) of the gneiss of Rupshu (*ante*, p. 640), where also the silurian formations are unrepresented, unless by the crystalline schists, that we may expect some radical difference between them; it may be that the central gneiss is largely represented in Rupshu. The two areas are separated by the trough of tertiary rocks, sedimentary and eruptive. A northerly dip seems to be as general in the Ladák gneiss as is the southerly one in Rupshu; so that the tertiary basin would seem to lie on the axis of a great anticlinal, in contact with the very lowest rocks of the Central Himalayas.

The eastern section of the Karakoram basin.—The observations made on the eastern traverse of the Kárákoram basin differ in so many points from those of the western route, that they are better given separately. The direct length of the former section on a line north by west, from the top of the silurian rocks at the Chángchenmo river to the Kuenlun gneiss near Sháhidula, is about 120 miles. The length of the western section in a north-north-east direction, from a corresponding point near the Nubra river, below the Saser pass, to Sháhidula, is about 90 miles, which is also nearly the distance between the two starting-points.

The passage from the trappoid silurian rocks south of Chángchenmo was not observed; but on the north side of the valley there are dark, often black, shales with sandstones. Traces of fucoids were found in these rocks, but no other fossils; from their relation to the triassic limestone, and their resemblance to the carboniferous rocks of Spiti, the beds are supposed to be carboniferous. Obscurely connected with these beds, near Kium, in the Chángchenmo valley, some recent-looking conglomeratic sandstones are noted as possibly related to the eocene deposits of the Indus valley.

The carboniferous series must be of considerable thickness, for it forms the Cháng ridge, north of the Chángchenmo valley, and the whole of the western portion of the Lingzhíthang; occurring again at the head of the Kárakásh river as far as Shinglung. Similar rocks were observed by Dr. Bellew on both sides of the Saser pass, and to the north of it. There is no mention of a calcareous rock in any of these sections.

A pale-grey triassic limestone, containing *Dicerocardium himalayaense* and *Megalodon triqueter*, occurs within the Chángchenmo valley, and is the most frequent rock, forming the ridges to the north. It is sometimes dolomitic and semi-oolitic, and is locally underlaid by a red brecciated calcareous conglomerate. On the border of the Lingzhíthang it is said to rest unconformably on the carboniferous shales. The last place where this triassic rock was observed was also at Shinglung, near the head-waters of the Kárakásh.

On this route Dr. Stoliczka observed no newer rock than the trias; but, as before mentioned, the ground was covered with snow at the time, and the difficulties of the journey were extreme. A little to the east, however, in the Lokzhung range, separating the Lingzhíthang plains from the larger area on the north, described by Mr. Drew as the Kuenlun plains, the last-named observer found a limestone containing hippurites, underlaid by ferruginous sandstone, lying unconformably on an older encrinitic limestone, dark grey in colour.[1]

At Shinglung, in the Upper Kárakásh valley, the carboniferous shales are followed immediately by the same chloritic rock noticed on the Lunkar-la, alternating with quartzose schists, and there regarded as silurian. At Kisiljilga ordinary slates alternate with red conglomeratic sandstones, and are succeeded by dark slates, which rock is described as occupying the ground to Aktágh, and thence across the Suget-la to near Sháhidula, on the Kárakásh, where the syenite of the Kuenlun begins. These silurian slates are expressly noticed as not metamorphic, and as corresponding with the metamorphic schists on the side of the Ladák axis.

The Karakoram section.—By the eastern route, Dr. Stoliczka approached Aktágh nearly from the east, and left it in a north-east direction; and the observations recorded are strikingly different from those made on the route from the north-west, and proceeding south-south-west to the Kárákoram pass. On the former route no mention is made of limestone anywhere near Aktágh; while on the latter limestone is by far the most conspicuous rock. Some miles below Aktágh, towards the Yárkand

[1] Jummoo and Kashmir, p. 343.

river, the silurian slates are overlaid unconformably (in the figured section they are quite parallel) by about 150 feet of reddish earthy and calcareous sandstones, passing into grey limestone and whitish marl, some 550 feet thick; higher beds are reddish and brownish, sandy and conglomeratic. No fossils were found in these rocks; but they are considered as probably carboniferous, and to be continuous from here with the similar rocks observed at Aktásh, east of the Pámir. At Aktágh there are some earthy and conglomeratic beds, resting on the edges of the carboniferous strata, and themselves considerably disturbed; they are conjectured to be tertiary. Proceeding towards the Kárákoram, the carboniferous rocks are regularly overlaid by a long sequence of triassic strata, dark and pale limestones and shales. A red limestone yielded *Arcestes johannis austriæ (?)*, *Ammonites batteni*, *Aulacoceras*, and Crinoids. Both carboniferous and triassic rocks are frequently traversed by a dark homogeneous greenstone, resembling basalt. At the Kárákoram the red triassic limestone is succeeded by blackish and grey marly shales which are overlaid by almost horizontal strata of brown limestone, very like the lower Tagling limestone, and containing fragments of *Belemnites*. These triassic rocks form the ridge at the Kárákoram pass. Some peculiar spheroidal fossils, known as Kárákoram stones, were observed to occur in dark shales below limestone taken to be triassic. They were described as Cystideans formerly, and have since been considered by various observers sponges or corals, but they appear to be types of a distinct class of animals, *Syringosphæridæ*, allied to the *Foraminifera*.

In his last day's notes Dr. Stoliczka records the occurrence of large boulders of syenite on the Dipsang plain, immediately south of the Kárákoram pass; and he draws the apparently obvious inference that this rock must be exposed *in situ* within the watershed, the extreme point of which at the head-waters of the Chipchak stream is only 25 miles to the east, and thus in the very centre of the stratigraphical basin. The route by the upper Kárakásh and over the Káratágh passed much closer to the upper Chipchak, on the east and north ridges of the same mountain crest, without any observation to suggest the proximity of crystalline rocks; so it is not impossible that the blocks in question may be true erratics, traces of the former extension of glacial conditions, of which almost every traveller in the Himalayas has made mention.

The Kuenlun range.—Dr. Stoliczka has given two sections of the Kuenlun; one on the west by the Yángi pass, and one fifty miles more to the east by the Suket pass, with which we must combine that of the Sánju pass on the same cross-section, over the northern or Kilián ridge of the same range.

The Suket pass section.—The relation of the slates forming the Suket pass, supposed to be silurian, to the syenitic gneiss, alternating with quartzose metamorphic schists to the north of it, in the Kárakásh valley about Sháhidula, is not stated. It is in these gneissic rocks that the old jade mines are placed, at about 20 miles up the Kárakásh, east-south-east from Sháhidula; and the gorge of the river, for 25 miles below Sháhidula, to the north, traverses the same formation. On the Sánju-pass the rock is chiefly a true mica-schist, with garnetiferous, chloritic, and quartzose varieties, in which jade was observed. In the Sánju valley, at Tám, some 20 miles north of the pass, the metamorphic schists are overlaid unconformably by dark, almost black, smooth slates, succeeded by grey conglomeratic sandstone belonging to some palæozoic formation. These dip at 40° to the north-west, but are again abruptly replaced by metamorphic schists, in which occur several massive beds of coarse porphyritic gneiss; these continue for 18 miles, to Kiwáz. At Kiwáz both sides of the valley are formed of conglomerates and red clays, said to strikingly resemble the supra-nummulitic rocks of the Sub-Himalayas and supposed to be tertiary. These have undergone contortion; and below Kiwáz they rest upon thick grey carboniferous limestone, containing Crinoid stems, Spirifers, and *Fenestellæ*. The dip in this rock is to the south-west, rising to the vertical, when it is succeeded by chloritic schist, which, after a mile or two, is in contact with red sandstone; and this again, at Sánju, is overlaid by calcareous sandstones and chloritic marls, some beds of which are nearly made up of *Gryphæa vesicularis* (*? vesiculosa*). This cretaceous group of Sánju is represented in the figured section with a low northerly dip, running up against the schists to the south, which somewhat reduces the difficulties of this rather anomalous sequence.

The Yangi pass section.—The second section of the Kuenlun corresponds only in a general way with that to the east. Some distance north of the pass there is a broad core of white granitoid gneiss, which is spoken of as the axis of the whole metamorphic mass. It is overlaid on both sides by schistose gneiss; and on the south this is overlain by black shale, grey sandstone and conglomerate, the whole series being spoken of as upper palæozoic. The coarse conglomerates are in great force at the Yángi pass (16,000 feet), and have a comparatively recent aspect, evidently forming the top of the series. They are identified with the beds at Tám, on the Sánju section. The lower, greenish and blackish, submetamorphic slaty or schistose beds turn up again south of the pass; and it is upon these that the newer rocks rest, as already described, near Aktágh. It must be remembered that all these details are derived

from uncorrected field-notes; and it is quite possible that had Dr. Stoliczka lived to publish his observations, he would have corrected them in many cases.

North of the gneissic axis there is a broader belt of metamorphic rocks, chiefly of a syenitic (hornblendic) character; and for a width of 16 miles the section is occupied by massive greenstone, which on the north is described as if, in part, a transformed condition of a bedded chloritic rock. This latter rock, with alternating white quartzose and calcareous schist, forms the Chiklik pass (10,400), at the north base of which it is succeeded by a thin-bedded limestone, also affected by metamorphism. This limestone increases to a great thickness, forming a belt some miles wide between the Chiklik pass and a point about 12 miles south of Kugiár. There is a reddish sandy band in the middle of it. The limestone itself is spoken of as grey dolomite. The dips are high and disturbed, but the prevailing direction is to the north. No fossils were found, and no suggestion is given as to the age of this limestone: it is presumably either carboniferous or triassic. No cretaceous beds were observed on this section.

The Pamir section.—A brief note of the section of the Pámir will be of interest, for comparison with those of the Himalayas proper. The direct distance in a west-south-west direction is about 220 miles from Ighiz-yar, at the edge of the Yárkand plains, at an elevation of 5,600 feet, to Kila Panjah, the capital of Wakhán, elevation 9,090, on the Oxus, at the confluence of the two western streams, from the Great Pámir on the north (elevation 14,320), and from the Little Pamir on the south (elevation 13,200). The drainage of the eastern side of the Pámir also flows to the Oxus, by the Aksu river (probably the original of Oxus) passing by Aktásh, elevation 12,800 feet. The main watershed lies close to the east of Aktásh, at the Nezatásh pass, elevation 14,900 feet, at about the centre of a synclinal basin, between the gneissic axes of Sarikol and the Pámir. The Pámir is placed at the apex, where the Mustágh and Hindukúsh ranges would meet, at an angle of about 120°, if prolonged on their general directions; but on the maps these ranges are represented as swerving southwards from the Pámir, and as being confluent in the range from which the Gilgit river flows south-eastwards and the Chitrál flows south-westwards, the pass to the latter valley from the Oxus having only 12,000 feet of elevation.

The mass of the Pámir is mainly formed of gneiss; a pale, fine-grained, mica-gneiss, which Dr. Stoliczka considered to be the same as the central gneiss of the Himalayas. It exhibits comparatively little disturbance, and is locally traversed by veins of albite granite, with mus-

covite. It is not distinctly stated whether this granite is intrusive. The correlation of this gneiss with the central gneiss is supported by the fact that the former is at many points immediately overlaid by black slates and shales, probably silurian, shewing very little alteration at the contact. The slates pass up into reddish sandy and conglomeratic beds. On the north-east, towards Aktásh, these rocks are overlaid by some 3,000 feet of limestone, both dark and pale varieties, considered as probably carboniferous; and these are succeeded by dark shales and limestone, in which, on the Nezatásh pass, *Halobia lommeli*, *Rhynconellæ*, and *Megalodon* were found, proving the triassic age of the rock. East of this the black silurian slates turn up, with a very steep underlie, and are thus in abrupt contact with the gneiss of Sarikol. The width of the Aktásh basin, between the two gneisses, is less than 50 miles. Intrusive greenstone is of frequent occurrence in the highest beds, as we have seen in the Kárákoram section, south of Aktágh. The Aktásh basin is, in fact, considered by Dr. Stoliezka to be the stratigraphical continuation of the Kárákoram.

The abrupt boundary of the Sarikol gneiss with the rocks of the Aktásh basin is probably faulted; for the relation of the same gneiss to corresponding beds on its north-east side is described as transitional, the palæozoic strata having undergone considerable metamorphism; and the gneiss itself is largely hornblendic and much disturbed. The Sarikol gneiss is about 25 miles broad, and is held to correspond with the crystalline rocks of the Kuenlun axis. Along the whole section to the north-east, 50 miles long, only lower palæozoic rocks were observed *in situ*; slates and sandstones, occasionally conglomeratic and earthy limestone, all without fossils; but debris of carboniferous limestone, with *Bellerophon*, was found in the lateral stream courses. Between Aktala and the gneiss there is extensive irruption of greenstone, like that south of Chiklik, on the Yángi section. The degree of disturbance diminishes in a very marked manner towards the plains.

The Kashmir-Pangi area.—This ground includes, as already indicated (p. 626), a pair of semi-detached synclinal basins, on the same strike, south of the Zánskár ridge, which is in elevation the principal continuation of the main Himalayan range. The Kashmir area coincides nearly with the upper basin of the Jhelum, and the Pángi area may be taken to indicate the upper valley of the Chináb, from the headwaters in Láhul to below Kilár. The irregular chain of ridges described (p. 631) as the Pir Panjál forms the south side of these basins; and the minor basin on the upper Rávi, in Chamba, between the eastern Pir Panjál and the Dhauladhár, belongs to the same group of terminal

features, on the divided prolongation of the main range. The following approximate classification of rock-groups in this ground is taken from Mr. Lydekker's paper[1]:—

	Kashmir and Pángi areas.	*Areas to north and east.*	*Age.*
a	Sandstones and slates of Zoji-la and Panjtarni.	Liláng series.	Rhætic and trias.
b	Upper limestones and dolomites of Amrnáth, Sonámurg, Mánasbal, and Drás river.		
	Limestones of West Kashmir. Blue limestones of Mánasbal. Limestones and slates of Marbal pass, Lidar and Upper Sind valleys, Kiol series (?). Great limestone of Jamn hills (?).	Kuling series. Król limestone (?) *Infra*-Król group (?)	Carboniferous.
	Upper Panjál slates, shales and trappoid rocks. Trappoid rocks of Walar lake.	Muth series. Blaini series.	Upper silurian.
	Lower Panjál slates; lower slates and trappoid rocks of Kashmir. Slates and limestones of Pángi, Láhul slates.	Bhábeh series. *Infra*-Blaini, or Simla slates.	Lower silurian and Cambrian (?).
	Gneiss of Pir Panjál. Upper gneiss of Wardwan and Zánskár range.	?	Cambrian.
	Central gneiss of Dárcha. Lower gneiss of Wardwan and Zánskár range. Dhauladhár gneiss.	Gneiss of Wángtu and Chor mountain.	*Infra*-silurian, but exact age not determined.

For convenience and clearness, we must again make a local exception to our rule, and describe the formations in descending order.

Triassic rocks of Kashmir.—As already mentioned (p. 631), the sedimentary series of the Zánskár basin, from the trias downwards, rolls over into the Kashmir basin, round the termination of the great gneissic mass of the Zánskár range. Although the feature is thus in the main a great anticlinal, the very crest of the ridge, at the Zoji-la, is formed of a sharp and locally inverted synclinal, in the highest rocks of the local series. It was this inversion that led Dr. Stoliczka to suppose that the sub-schistose sandstones at the Zoji-la were carboniferous, from

[1] Rec. G. S. I., XI, p. 63.

their apparently underlying triassic strata. Mr. Lydekker found the same rocks to the south-east near Amrnáth and Panjtarni to be distinctly folded in a trough of the dolomitic limestone. The age of these limestones is well fixed north of the Zoji-la. Dr. Stoliczka observed a great thickness of light-blue limestone forming the banks of the Drás river, and containing numerous small bivalves, like *Megalodon columbella*, Hornes, from the upper trias of the Alps. It is overlaid to the south by a darker dolomitic limestone, apparently identical with the Pára limestone of Northern Zánskár. South of the Zoji-la, Dr. Stoliczka found *Ammonites gerardi* in the limestones and carbonaceous slates near the camp Thájwaz in the Sind valley, proving them to belong to the Liláng group of Zánskár.[1] There would seem, however, to be great variability in the composition of these groups. Mr. Lydekker (*l. c.*, p. 45) identifies the white dolomite of Amrnáth with the Pára limestone north of the Zoji-la; and in the Chandanwarí section (*l. c.*, p. 44), at the head of the Lidar valley, a set of slates and sandstones separates these white dolomites from the dark-blue carboniferous limestone, and is interstratified with both of them. This apparent transition between carboniferous and uppermost triassic strata calls particularly for further examination. Triassic rock has as yet only been observed in one other locality in the area under notice; it is in the Kashmir valley, in the promontory south of the Mánasbal lake, where the white dolomite overlies the compact blue carboniferous limestone.

Carboniferous rocks of Kashmir.—With the exception of the very local occurrence of the triassic limestone on the north side of Kashmir, as already mentioned, only palæozoic and gneissic rocks are found throughout the rest of the area under notice, in which condition this ground exhibits a partial affinity with the Lower Himalayan area. Of the palæozoics, again, only the upper members have been fully recognised by fossil evidence; and in this way they have scarcely been traced beyond the limits of Kashmir, where they are almost confined to the north side of the valley. We must notice these rocks first, as it is through comparison with them that the position of other groups has been provisionally determined.

The identification of carboniferous rocks in Kashmir is of old standing. Fossils are locally abundant, but no large collection of them has been made. The following species of carboniferous *Brachiopoda* were described by Mr. Davidson[2] from specimens collected by Captain

[1] Mem. G. S. I., V, p. 349.
[2] Q. J. G. S., XXII, 1866, p. 39.

Godwin-Austen near the villages of Khunmu, Bárus, and Zewán, in the Vihi valley, immediately to the east of Srinagar :—

Terebratula sacculus.
Athyris subtilita, Pl. I, fig. 4.
Spirifera keilhavii, Pl. I, fig. 1.
Sp. vihiana.
Sp. kashmiriensis.
Sp. moosakhailensis, Pl. I, fig. 2.
Sp. barusiensis.
Rhynconella barumensis.
Rh. kashmiriensis.
Streptorhynchus crenistria, Pl. I, fig. 7.
Productus semireticulatus, Pl. I, fig. 8.
Pr. scabriculus.
Pr. humboldtii.
Pr. spinulosus.
Pr. lævis.
Chonetes lævis.
Ch.? austeniana.
Discina kashmiriensis.

Two measured sections from this neighbourhood by Captain Godwin-Austen[1] will shew the local composition of the series. The fossils were principally found near the very base of the formation; and it would seem from his figured sections that the bottom quartzite is unconformable to the underlying hornblende slates; but as no statement is made to that effect, the point is doubtful. The appearance is probably due to the locally unstratified condition of the trappean upper silurian rocks.

Section along a spur from Wasterwán, between Bárus and Reshpur.

	Feet.
8. Hard compact limestone, weathering light ochre	100
7. Hard compact limestone, no fossils	410
6. Grey limestone, weathering light-brown	200
5. Micaceous sandy limestone; *Spirifera rajah*, and *Productus semireticulatus*	60
4. Slaty shale	15
3. Shaly limestone, weathering green, full of fossils	40
2. Hard fossiliferous limestone	80
1. White quartz rock	15
Hornblende slate	
	920

Section at the foot of a ridge from Zehanwán.

	Feet.
7. Hard compact crystalline limestone, of a dark blue-grey, interstratified with grey shales, which weather to a green tint, very fossiliferous	20
6. Calcareous shales, very fossiliferous	30
5. Alternations of shaly slate and sand	30
4. Sandstone containing water-worn pebbles	2
3. A bed of water-worn pebbles and shingle, of quartz and hornblendic rock, imbedded in a sandy crumbling matrix	4
2. Altered sandstone and shaly beds, very hard and splintery	15
1. White flinty quartzite	12
Hornblendic slaty rock	
	83

[1] Q. J. G. S., XXII, 1866, p. 29.

Owing to the excessive disturbance all these strata have undergone, and the deep erosion of the ground, the upper members of the stratified series are only found in isolated masses along the inner edge of the valley, and in the hills to the north. No carboniferous rocks have been observed on the south-west side of the valley, on the flanks of the Pir Panjál; but at the south-east end of the valley, south of Sháhábád, the rocks of the Pir are in faulted contact with the mass of carboniferous limestone, which here closes the valley, and stretches for a few miles beyond the watershed at the Marbal pass. The general structure is that of a broad complex synclinal fold, the axis rising to the south-east. At the north-west end of the valley also, at Trigamma, the carboniferous limestone is in force, occupying a synclinal fold in the slates. Near Sháhábád Mr. Lydekker describes the sequence as consisting of dark-brown sandy shales, gradually becoming calcareous, and so passing up into the characteristic dark-blue carboniferous limestone, which is overlaid by yellowish and whitish sandstones. These highest beds are often replaced by banded limestone, and may represent the trias.

From the examination of many sections, Mr. Lydekker concluded that the carboniferous rocks are normally in conformable sequence with the underlying slate series. This relation is seen in the section near Eishmakám, in the Lidar valley, north of Islámábád, where the following beds are in regular succession, No. 1 being silurian and Nos. 2, 3, and 4 carboniferous:—

4. Slates and sandstones with *Fenestella, Productus,* and *Spirifera.*
3. Sandstones and dark-blue limestones, with corals and crinoids.
2. White and blue sandstones.
1. Blue or green slates and amygdaloids.

The proportion of limestone in the carboniferous series is very variable in different sections.

Silurian rocks of Kashmir.—It is upon the strength of this close connection with the carboniferous strata that the underlying series is taken to be silurian; for not a single fossil has been found in these rocks throughout the whole of this region. They are, however, continuous with rocks in corresponding relations to the carboniferous group in Zánskár, where silurian fossils do occur (p. 638), though far less abundantly than farther east in the Hundes basin (p. 649). The absence of organic remains is only very partially accounted for by the greater metamorphism of the strata in the north-western area.

Another cause of doubt regarding the correlation of the different formations in Kashmir has been the extensive occurrence of trappean rocks, and the uncertainty as to their relation to the sedimentary series,

and, therefore, as to their age. All the rocks have been so contorted, that special examination was needed to distinguish effects of irruption from those resulting from a disturbance common to all, the local appearances being superficially very deceptive: thus north-east of Mánasbal there is a dome-shaped mass of amorphous greenstone, with the carboniferous limestone dipping from it on three sides. Such appearances are very suggestive of intrusion; and so the prevailing opinion has been, that the trap of Kashmir and the Pir Panjál is of later date than all the contiguous formations. Mr. Lydekker, however, comes to the conclusion that the trap is altogether pre-carboniferous, no single instance of true intrusion having been found; and the general distribution of the rock clearly points to its cotemporaneity with the upper silurian strata.[1] In Northern Kashmir, especially about Srinagar, Mánasbal, and the Walar lake, the massive amorphous forms of greenstone are predominant; but even with these there are associated stratified earthy and amygdaloidal beds, identical with those which all through the Pir Panjál and elsewhere are characteristic of the upper zone of the slate series. To a great extent these beds are of a mixed nature, containing much silicious detrital matter with the trappean ingredient, and their trappoid character is further to some extent due to partial metamorphism; but there can scarcely be a doubt that the peculiar facies of the upper silurian zone of this region (and it seems to extend also to the western part of the Zánskár area) is due to cotemporaneous eruptive action. The following general sequence of the strata composing the lower palæozoic rocks, forming the slate series, is taken by Mr. Lydekker (*l. c.*, p. 39) from the section of the Pir Panjál pass:—

5. Greenish slates, sandstones and amygdaloidal rocks.
4. Black and green slates with brown sandstone conglomerate, containing pebbles of quartzite and slate.
3. Whitish quartzites and sandstones.
2. Black slates containing pebbles of gneiss and quartzite.
1. Granitoid gneiss, with occasional bands of slate and quartzite.

The relation of the palæozoic slates to the crystalline series is a point of special interest and difficulty, as has been shewn in other cases (p. 640). In the region under notice Mr. Lydekker has found this relation to be one of inseparable association, as is indicated in No. 1 of the preceding section of the rocks in the Pir Panjál. The same condition obtains on the north-east, with reference to the gneissic mass of the Zánskár range; as is well

[1] Dr. Verchère (J. A. S. B., XXXV, 1867, p. 86) had announced the same conclusion; but this writer's views are not always supported by sufficient evidence to be accepted.

seen in passing from the south-east end of Kashmir, by the Margan pass, to the Wardwan, and down the latter valley to Kishtwár. It is not merely a case of gradual transition of metamorphism, but also complete association by interstratification of slaty and gneissic rocks, and their equal participation in the results of disturbance. Some of the bands of gneiss thus intercalated with the slates are quite massive and granitoid, both fine-grained and porphyritic. The contrast is altogether most striking between this mode of relation and that of the slates to the central gneiss of the Lower Himalayan region; and the inference is, that the gneiss of Zánskár is to a great, but unknown, extent made up of converted palæozoic strata. Abrupt contact is here also found between the two types of rock; but they are more or less distinctly due to dislocations, as at Krur in the lower Wardwan valley.

The Pangi basin.—Below Kilár, the gneissic rocks of the Zánskár ridge pass well to the south of the Chináb; and it is not known whether they are not there confluent with the gneiss of the Pir Panjál chain, thus separating the slates of Pángi from those of Kashmir. There can scarcely be a doubt that these two belong to the same lower palæozoic series; but there are some noteworthy differences of composition. The trappoid rocks have not been observed in Pángi; it may be because the eruptive action did not extend so far, that zone being represented by ordinary slates; or, only the lower members of the series may be represented in Pángi. Bands of limestone are not very rare in the Pángi slates, although entirely wanting in the Kashmir area. The quasi-erratic boulders in the black slates of Pángi, as already mentioned (p. 632), are very peculiar; although these slates are probably the local representatives of the zone No. 2 of the Pir Panjál section in the list already given. The relation of the slates to the gneiss in Pángi is not exclusively like that described in the Wardwan valley: in introducing the Pángi slates, Mr. Lydekker (*l. c.*, p. 54) describes a very thick band of granitoid gneiss as conformably overlaid by a newer series of bluish slates and sandstones, which contain no truly metamorphic rock. At the east end of the basin, the junction of the slates with the gneiss of the Rotáng pass would seem to be of the same abrupt kind. Yet on a parallel section to that at Kilár, about Tingrat, in the valley north of Triloknáth, there is an alternating passage from the slates to the gneiss. It is by the close comparison and connected survey of such contrasting sections, that we may ultimately expect to separate the two very distinct gneissic formations, which we are almost forced to think must be present in this ground (p. 630): the central gneiss, of long pre-silurian metamorphism; and a lower silurian or cambrian gneiss, made out of, and

associated with, deposits that have undergone little or no change in adjoining areas.

The Pir Panjal chain.—The extension already given (p. 631) to this name of the range outside (south-west of) Kashmir, to include the ridges in approximate continuation of it to the south-east, although separated by the gorge of the Chináb below Kishtwár, may be upheld geographically; but geologically (as based upon structural equivalence) it is still provisional, for we have no observation of these hills south of the upper Chináb valley. So far as we know, the slates of Pángi may be continuous with those of the upper Rávi valley, without any dividing gneissic axis. In this south-eastern ground, too, the range in question is not the outermost range of the older formations, for the Dhauladhár lies to the south of it; and it may be to this condition, of an outside position in the mountain system, that is due the peculiar structural character noticed in the Pir Panjál and Dhauladhár ranges—that of a great folded flexure, with inversion on the outer side. This peculiarity is, perhaps, opposed to the connexion of this ridge with the central region, of which it is thus here a specially marked marginal feature. Its affinities are, however, much closer with the area of normal Himalayan disturbance, than with the Lower Himalayas, where the structure is quite different (p. 602).

Mr. Lydekker has clearly shewn this structural character at the Banihál pass,[1] and at the Pir Panjál pass[2]; and the same feature had previously been noticed in the Dhauladhár.[3] In proceeding from Kashmir across the Pir Panjál pass, the sequence of rocks given above (p. 663) is observed in descending order, the beds dipping towards the valley. The dip increases steadily, and becomes vertical in the gneiss; then the black slates (No. 2), with pebbles of gneiss, come in again, but with a steep underlie towards the gneiss; and they are succeeded at the crest of the pass by the white quartzites, having the same inward dip; under these again come the greenish trappean beds of zone No. 4; the whole series, many thousand feet in thickness, being clearly inverted on the south side of the axis.

On the outer margin of the range, in the inverted series, higher (apparently lower) beds are preserved than on the side next the valley. They consist principally of limestone, with a variable proportion of associated black and greenish shales and pale sandstones. From their conformable and transitional relation to the trappean upper silurian zone,

[1] Rec. G. S. I., IX, p. 161, 1876.
[2] Rec. G. S. I., XI, p. 39, 1878.
[3] Mem. G. S. I., III, Pt. 2, p. 63, 1864.

Mr. Lydekker concludes that they represent the similar, but fossiliferous, rocks in a like position in Kashmir, and are therefore carboniferous. This band of limestone is more or less continuous at the edge of the higher mountains, from the Pir Panjál to the Lower Himalayan area; and it is upon this remote and slender connexion that the Król limestone, capping the slate series in the Simla region, is taken to be carboniferous. The identification of the great limestone, forming the large inliers of the Sub-Himalayan zone (p. 562), from 4 to 12 miles distant from the base of the Pir Panjál, as carboniferous, is perhaps equally open to verification. If all the limestone of those inliers is carboniferous, the deposits of that age increased enormously in thickness within a very short distance; but this inequality of deposition has been very generally observed in the carboniferous rocks of the Himalayas.

The fact that the gneiss partakes so regularly in the disturbance of the slates, would seem necessarily to imply original complete conformity of stratification between them; and therefore the probability is, that all the metamorphics of the Pir Panjál belong to the newer gneiss. It may also be suggested that this form of disturbance, a great regular folded flexure, could hardly have occurred here had there been a primitive ridge of old gneiss occupying the position of the present axis; from which we may suppose, that if the central gneiss is represented here, its elevation is altogether due to post-silurian disturbance.

There are, however, certain irregularities in the feature as a whole, that necessitate some modification of the view of it as a single and simple anticlinal flexure. The outcrop of the core of gneiss is not continuous; nor does it observe a strictly uniform direction throughout. These irregularities, moreover, are not superficial; thus, in the deep gorge cut by the Jhelum through the range, between Báramúla and Uri, the gneiss does not appear at all; and the slates, in some manner not yet worked out, wrap round the termination of the gneissic mass of the ridge on either side. The abruptness of these breaks has suggested the possibility of their connexion with primitive ridges of old gneiss; but this supposition is so difficult to reconcile with the general symmetry of contortion, that we must seek for some other explanation. Since the main feature is not a simple flexure, but includes also some minor foldings of the strata, as is observed in both the Banihál and Pir Panjál sections, it is natural to suppose that at different points of this range the maximum effect took place along different minor axes of initial contortion, resulting, of course, in ultimate discontinuity, and partial discordance between these elements of the great flexure.

One-sidedness of mountain structure.—It has been already remarked (p. 559) that the structural form of the Pir Panjál and Dhauladhár ranges corresponds with that of the ridges of the adjoining Sub-Himalayan rocks. It may perhaps also be inferred that a similar structure prevails in the Zánskár range, but nothing very like it has been described in the interior mountains, nor yet, which is more noteworthy, at the northern margin of the mountain region; the features of the hills on the borders of the Yárkand plains, so far as we know them, bear no resemblance to those of the Southern Himalayas. This one-sidedness of mountain structure has been observed elsewhere, and has given rise to the opinion already alluded to (note, p. 529), that the source of disturbance was external to the mountain region.[1] This notion, however, is decidedly obscure; almost on a par with the original idea of simple upheaval, so long in favour with Alpine geologists. It seems more natural to look for an explanation of the dominant structural form, in any area of special disturbance, to the resultant condition of resistance at the time of compression. Such a local condition has been intelligibly assigned by Mr. LeConte,[2] in the unsymmetrically lenticular form of the total sedimentary mass, from the alteration and compression of which a mountain range is formed, whereby excessive contortion and over-thrust takes place on the side of the most rapid decrease of thickness of the deposits, which would generally be the landward side. This explanation may be partially the correct one for the case under description, although there would still be some difficulty in connexion with the part that has been assigned to the central gneiss of the Lower Himalayas. But it is evident that this particular condition is only one in the many possible combinations by which the position of least resistance under compression may be determined.

Post-tertiary and recent formations.—It has been already explained (p. 371) how difficult it is to draw a distinct line between tertiary and post-tertiary formations in Peninsular India. Indeed, it is sufficiently evident from general considerations that, unless upon the assumption of a world-wide or half world-wide coincidence of phenomena, there

[1] Suess: Die Entstehung der Alpen. An abstract of this work is given in Silliman's Journal, 1875, p. 446.

[2] American Journal of Science and Arts, August 1878, and elsewhere.

Mr. J. LeConte (and he is not singular in this) seems to have overlooked the fact that a very large and vital a part of his theory is contained in views admirably expounded long ago; it is by no means evident in what particulars, as a "formal theory," the "geanticline" differs from De Beaumont's *bossellement*, or the "mashing" from the *écrasement* of the same author; or how the part played by "sedimentation" in the origin of mountains differs from that assigned to it by Herschel and Babbage. The little progress geologists have made has been in applying the ideas of these physicists to actual cases of mountain-structure.

can be little or no correspondence between the great breaks in the sequence of geological formations in distant parts of the earth's surface; and the chief interest of the case under immediate notice is, that the traces of such a half world-wide event have been observed in the Himalayas. On the page above referred to it was stated that the limit between tertiary and post-tertiary formations in Europe is most conveniently marked by the glacial epoch; and on the following page it was shewn that India had been affected by the glacial period, and that Himalayan glaciers were formerly more extensive than they now are. That evidence need not be quoted again here; we would only draw attention to the fixing of the date and the cause of that former extension, as necessary features of the important question at issue—the validity and force of the words "epoch" and "period," as applied (without local affix) to glacial action; for, as so used now, they imply a half world-wide, if not a world-wide, coincidence of the phenomena; and the importance of verifying this application is very great. Even if one such event could be established, it would be of immense service, in giving a rough general datum line in past time from which to correlate the progress of geological changes; for at present there is no greater obstacle to exact speculation in geology than the utter uncertainty between local and true time, as indicated by the palæontological clock.[1] It will require a great accumulation of connected observations to establish the cotemporaneous glaciation of even a hemisphere of the earth—to shew, for instance, that the facts appealed to are not successive, and due to a progressive change, more or less irregular, such as would be caused by a shifting of the earth's axis, although the possibility of this particular occurrence has lately been denied by competent physicists. In such a case the expression "glacial epoch" would have little more exact significance than have now the various palæontological periods.

Sub-Himalayan high-level gravels.—The evidence for a stratigraphical break in the formations of India, equivalent to the pliocene-pleistocene change in Europe, is not found most distinct in the same localities as the best evidence for an extension of glacial action. The latter naturally occurs in the higher ground, towards the region of existing glaciers; the best instances on record being those in Sikkim (*supra*, p. 373) and Kashmir.[2] The former, as naturally, is found in connexion with the known tertiary deposits in the Sub-Himalayan zone. Nothing could be more sharply defined than the separation of the high-level

[1] *e. g.* Dr. John Evans' objections to Professor Haughton's considerations on Changes of Climate in past times. Presidential Address (Geological Section), British Association, 1878, "Nature," Vol. XVIII, p. 418.

[2] Drew: Jummoo and Kashmir Territories, p. 219.

gravels along the base of the North-Western Himalayas, from all recent deposits on the one hand, and on the other from the latest rocks of the tertiary series—the topmost Siwaliks. In the section already so much quoted of the Sutlej gorge above the Bubhor (p. 551), those gravels are found capping the low hills, at an elevation of 500 to 600 feet over the river, and resting undisturbed on the edges of vertical Siwalik conglomerates. The same may be seen in many other places, as in the river section of the Rotás ridge, west of Jhelum; and it will scarcely be disputed that, from stratigraphical analogy, they may take provisional rank as early pleistocene. In the places indicated they are made up of thoroughly water-worn torrential debris, but in certain positions, as in Kángra, they have a character that seems to demand the aid of glacial conditions; and this only occurs when there is an obvious source of such an influence. The whole Kángra valley and many other dúns were once more or less filled with these deposits. The boulder gravel caps ridges above Kángra fort, on the southern side of the valley; and all about, especially on the inner side of the valley, huge blocks of gneiss are scattered. These blocks are not traceable to distinct moraines; but they often occur in sheltered positions, to the side of the actual gorges, where they must have arrived by flotation, or else have fallen over the present flanking ridges when these were smothered in a great fan-talus of diluvium from the main ridge of the Dhauladhár close by. No scratching or polishing has been found either on the blocks, or on the rocks *in situ*; but all the facts very strongly suggest that glacial conditions must have aided in producing such results. The elevation of this sub-glacial deposit in Kángra is between 2,000 and 3,000 feet; the crest of the Dhauladhár, from 6 to 8 miles distant, rising to 14,000 and 16,000 feet.

Glacial evidence in Tibet.—The effects, real or imputed, of glacial action in the Alps and elsewhere are so prodigious, that, after accepting some clear cases, such as those quoted in Sikkim and Kashmir, of old moraines at elevations of only 6,000 to 8,000 feet, one is surprised to find that traces of glaciation are not more conspicuous elsewhere in the Himalayas at vastly greater elevations, in Tibet. At least, but slight mention is made of those traces by very competent observers. Dr. Stoliczka may be said to have ignored the subject; Colonel Godwin-Austen, who surveyed the highest regions of Western Tibet, and who from the first paid attention to geological features, only makes casual mention of glacial extension, generally in its least certain form—that of presumed erratics; and Mr. Drew, who enjoyed such exceptional opportunities of studying the ground, and who paid particular attention to this subject, as is proved by his admirable account of the superficial deposits of Western

Tibet,[1] makes less distinct mention of glacier extension here than at much lower elevations to the south. He does, indeed, describe deposits of the glacial period, but as being scarcely different from the actual torrential deposits: and to the other marks of glacier-action there is very little allusion. The spurs at the edge of the Deosai plain are said to shew signs of ice-moulding,[2] and a few instances of contorted alluvium are attributed to the presence of glaciers at lower elevations than at present; but Mr. Drew's chief argument, so far as his work has proceeded, for the influence of the glacial period in Tibet is the indirect one—to account for the excess of disintegrating action, whereby the river valleys became choked with diluvial matter. It is even remarked (*l. c.*, p. 470): "Whether in that period there was any variation in the transporting power of the streams, I do not at present see my way to determine; the material is, as a whole, of the size that is even now brought down by the streams, taking the spring and occasional floods into account." What these occasional floods may do has been already stated (p. 516). On the whole, the published descriptions of Tibetan regions are not what might be expected, had the ground been deeply covered by ice, as would surely have been the case at a time when on the southern side glaciers reached so low as 7,000 feet. But these doubts are only conjectural, and intended to elicit further research.

The Hundes lake-basin.—The immense extent of what we may conveniently (until we know more about them) call "post-Himalayan deposits" in Tibet has already been indicated in our remarks on the plain of Hundes (pp. 646-51); where some doubt was hazarded as to whether the remains of the extinct mammalia were really derived from the undisturbed deposits of that high-level basin. If the "glacial epoch" test might be applied here, it would confirm the supposed Siwalik age of these beds; for General Richard Strachey mentions the existence of old moraines upon them.[3] From an observation recorded by Captain Henry Strachey[4] it would seem that they are truly lacustrine: he speaks of the ground by the name "*Guge*," and says that the deposits "appear to consist of more finely comminuted material in their central part, where furthest distant from the mountains, the great ravines there being flanked by cliffs half a mile high, which exhibit throughout their thick-

[1] Drew: "Alluvial and Lacustrine Deposits and Glacial Records of the Upper Indus Basin," Q. J. G. S., 1873, XXIX, p. 441; and "Jummoo and Kashmir Territories," 1875.

The paper in the Quarterly Journal is headed Part I, and only treats in detail of the alluvial deposits; it is understood that the "Glacial Records" were to have been described in the second portion of the paper, which has not yet been published.

[2] Q. J. G. S., XXIX, p. 466.

[3] Q. J. G. S., VII, p. 310.

[4] "Physical Geography of Western Tibet," Jour. Roy. Geogr. Soc., 1853, XXIII, p. 19.

ness a fine homogeneous clay with little gravel in it. The stratification of the alluvium seems to be horizontal in all cases, or at most very slightly sloped from the mountain foot to the valley middle, in accordance with the existing directions of the drainage. I have once or twice seen small faults, where some of the strata had become canted from the horizontal for a few yards; but never anything like a general disturbance of the original position."

It is not known whether this great lake-basin is now a rock-basin, or if it ever was; and, as we shall see, there are other larger and more lofty lake-areas, the origin of which is distinctly attributed to the damming up of the gorge of discharge. The fact that the gorge and the deposits themselves have been re-excavated to so great a depth, is another point in favour of the greater antiquity of the Hundes deposits; and, on the whole, the balance of evidence is in favour of their being of late tertiary (Siwalik) age. It would be a crowning proof of the fact, already sufficiently established (p. 570), that the great Himalayan river-basins existed in Siwalik times, as now. A comparison of the state of these deposits with that of the older tertiary deposits of the Indus valley, is a further suggestion, that the post-Siwalik disturbance was quite a minor, or collateral, effect of that which produced the contortion of the mountains.

Lingzhithang and Kuenlun lake-basin.—The great lake-basin of Lingzhíthang, and the Kuenlun plains,[1] are in a much newer phase of existence than that of Hundes, although of greater extent, and at a higher elevation. They stand at the main Himalayan watershed, north of the Indus; and have apparently been reclaimed from the northern drainage area. They are now in the last stage of extinction as lakes, having numerous small shallow tarns and ponds of salt water still left in the lowest depressions. They occupy an area 100 miles long from north to south, with an average width of 70 miles, divided by the Lokzhung mountains, or what is left of them; for the watershed in the gorges is only 300 feet above the southern plains, and altogether on gravel; while some of the peaks range to 21,000 feet. The Lingzhíthang plain, on the south, has an elevation of more than 17,000 feet, and the Kuenlun plains 16,000. The original outlet is supposed to have been at the north-east corner, into the eastern Kárakásh valley. This became choked by fan-deposits from the lateral gorges; and so the lakes were formed, and ultimately the plains.

Tso Moriri and other basins.—Mr. Drew describes several other similar areas, on a smaller scale; such as the little salt-lake plain of

[1] Drew: "Jummoo and Kashmir Territories," p. 331.

Rupshu, and the saline lakes of Pángkong and Moríri—all attributed to the same mode of formation. The Tso Moríri gives the most distinct illustration of this process; the Phirsa stream brings down to the main valley more debris than it can carry on, and thus has raised a dam across the valley. The greatest depth of the lake is 248 feet; but the fan of the Phirsa apparently has that depth, besides being now, at its lowest point, about 100 feet higher than the lake.

Around all these lakes and lake-plains there is clear evidence that the waters have formerly stood at a much higher level. This fact points to a continuance of the cause which originally gave rise to these lakes—a progressive decrease of precipitation and increase of evaporation, whereby the carrying power of the streams has become more and more out of proportion to the rate of disintegration of the rocks.

Alluvial deposits of Tibet.—This clear evidence of a change that is still in operation is the more noteworthy, as it is apparently the reverse of a process which is appealed to in explanation of a more widespread development of other deposits in the valleys of Tibet. Mr. Drew makes a very important distinction between lake-deposits and river-deposits, or alluvium; the principal criterion being the horizontality of the former, their lamination, and the absence of larger, current-borne materials: and he considers that the great accumulations of debris found in almost every valley, high above the present stream level, are river-deposits, not lacustrine; also, that they were deposited since the valleys were eroded to about their present depth; and that, therefore, a double change took place in the relative carrying power of the streams, before and after the formation of those deposits. In this case the changes of balance are accounted for by the abnormally increased disintegrating action from the cold of the glacial period; to which time these beds are thus relegated. This is, in fact, the principal evidence referred to for the glacial epoch in Tibet. The general description of the nature of these deposits is quoted above (p. 670); and it is hardly what one would have expected from the supposed conditions. May not these old valley deposits be in part the result of temporary lakes, such as may at some time or other have been formed by obstructions at different points of the deep valleys; and in part, deposits of the time when the valleys first stood at those levels? The Indus is now laying out alluvial plains at several points of its valley in Ladák.

The Kashmir basin.—None of the Tibetan lake-basins, actual or extinct, are known, or supposed, to be rock-basins. Indeed, they are plateaus as much as basins, on account of their elevation, and because the height and width of the lip separating them from ground at a much

lower level are inconsiderable. This is remarkably the case with the Lingzhíthang basin. The Kashmir valley is much more basin-shaped. Its length is about 84 miles, and in width it varies from 20 to 25 miles; the lowest elevation is 5,200 feet, the mean for the whole valley being about 6,000 feet, or 5,000 feet above the plains of the Punjab, from which it is separated by the Pir Panjál range, the lowest pass in which is 3,000 feet over the valley. Kashmir is still in part a lake-basin, and a much larger part is occupied by very low alluvial land, formed by the overflow of the actual rivers; the rest is occupied by flat terraces and plateaus, from 100 to 300 feet above the alluvial surface, and known by the vernacular name *karewas*. Both surfaces rise as they come within the influence of torrents and rainwash from the surrounding hills; in this way the karewa surface rises to an elevation of 7,000 feet.

Colonel Godwin-Austen[1] observed that at the outer edge of the valley, especially on the south-east, the karewa deposits have an inward dip of more than 20°; and he estimated their thickness at 1,400 feet. Throughout this thickness the remains of recent, land and fresh-water, shells were repeatedly found, also plants and fish scales; peaty layers also occur at several horizons, indicating a succession of land surfaces, alternating with the lacustrine deposits. Mr. Drew[2] confirms the opinion, that the karewa deposits are lacustrine and not alluvial; but he seems (*l. c.*, p. 212) to suggest a distinction between these disturbed beds and the material of the karewas proper. Mr. Lydekker,[3] however, describes a perfectly gradual transition from the disturbed blue clays and conglomerates on the outer side of the valley, up into the horizontal pale fine sands and loamy clays forming the plateaus in the centre and on the inner (north-east) side; but he suggests the convenient distinction of upper and lower karewa deposits, and considers that the former may be of upper Siwalik age.

It seems most likely that these deposits now lie in a rock-basin, the tilting of the lower strata probably corresponding with a late relative rise on the side of the Pir Panjál. Colonel Godwin-Austen and Mr. Drew, however, only refer to possible obstructions in the Jhelum valley in connexion with the old lake; although the latter observer (*l. c.*, p. 211) contemplates its having risen to a level of 7,000 feet above the sea, that of the highest karewa slopes, or to 1,800 feet above the present lowest level of the valley. The possible source of doubt in this estimate lies in the uncertain distinction between true deposits in water and the results of

[1] Q. J. G. S., XX, p. 383.
[2] "Jummoo and Kashmir Territories," pp. 161 to 212.
[3] Rec. G. S. I., XI, p. 32.

rainwash. Mr. Drew decides that the ancient buildings in Kashmir are subsequent to any but the recent deposits of the valley; and no relics of man have been found in any beds older than recent. No undoubted marks of glacial action have been observed in Kashmir lower than 500 feet above the valley; the evidence of such action at a lower level is so far confined to quasi-erratics in or about the gorge of the Jhelum.

The Nepal valley.—The only other valley at all comparable with that of Kashmir is Nepál,[1] in the Lower Himalayan area. The superficial differences correspond with those that mark the structural characters of the two regions; both are longitudinal valleys, lying in the general strike of the strata; but the clear open oval area of Kashmir approximately coincides with the elliptical synclinal depression of the calcareous upper palæozoic strata, a form that is so generally marked wherever the Himalayan disturbance has been unobstructed. Nepál, on the contrary, is rather a group of confluent valleys, with high dividing spurs: in both directions, on the prolongation of the strike of the rocks, there is a continuation of the special excavation of the mountain zone; and the rocks of this zone being prevailingly calcareous, has suggested the conjecture (*l. c.*, p. 92) that the feature is primarily due to erosion by solution; as may also be the case with Kashmir. Another cause, however, and the proximate one (*l. c.*, p. 100), of the formation of a lake-basin in Nepál, was probably, in part, a relative rise of the hills on the south; for here, too, the bottom beds of the valley deposits have undergone local disturbance on this side.

These deposits correspond very closely with those of Kashmir. There is no remnant of a lake; but the other features are alike. An extensive upland area, known as *tánr* land, corresponds to the karewa of Kashmir, and to the bhángar of the Gangetic plains. It is the surface of the old lake-deposits, no doubt considerably modified by waste in the central parts, and by rainwash accumulations near the hills. The streams flow at a depth of from 50 to 500 feet below this surface, according to position; but here too, as in Kashmir, they are now, for the most part, subject to overflow, and thus form the alluvial valleys, known as *kholas*, the khádir land of the plains (p. 403). Beds of serviceable peat, much used for brick and lime burning, occur at various levels in the valley deposits; and there is also a blue clay, extensively used for top-dressing the fields, and the fertilising virtue of which seems to be due to the phosphate of iron (vivianite) freely scattered through it in blue specks. No fossil remains have, as yet, been found in any of these deposits. Any

[1] Rec. G. S. I., VIII, p. 93.

trace of glacial action is also wanting in Nepál; not even the doubtful erratics occur. But such could only be expected on the assumption of very advanced glacial conditions; for Kathmándu is only 4,509 feet high, and the valley is not traversed by any river from the snowy range, but forms the head-waters of the Bághmati; the highest summit of the surrounding ridges being Phulchok, on the south of the valley, with an elevation of 9,720 feet.

Other lakes.—There are a few insignificant lakes near the outer fringe of the mountains, which may be accounted for in the same way, or by obstruction caused by landslips. A cluster of such ponds lies about Naini Tál[1]; and some occur also in the Sub-Himalayan zone, as at Kundlu, on the road from Rupár to Belászpur. Mr. Mallet describes[2] some tiny lakes at the edge of the tertiary zone in Sikkim, as formed by landslips. In one, the stumps of the trees that were growing on the sides of the valley at the time, are still standing.

It is apparent how very different are the lakes, actual or extinct, of the Himalayas from those of the Alps; the distribution of lacustrine rock-basins in the latter ground being as markedly marginal and transverse, as in the former it is internal and longitudinal. Yet it is quite possible that both may be principally due to a like cause—changes of level in the mountain mass, due to lateral pressure, which would take effect variously, according to the form and dimensions of the ground affected.[3]

Drainage lines.—In connexion with the alluvial and related deposits, a few suggestions may be made regarding the drainage. Rivers are one of the most palpable, most widespread and ceaseless agents of geological changes; and dwellers in India have before them unsurpassed examples of the magnitude of their operations, both for construction and destruction. Yet we have hardly outlived the time when much of this river-action was ignored. Until recently, the deposits forming the great Indo-Gangetic plains were regarded as of marine origin. The positive, constructive action of rivers is now better understood, as it is, of course, more open to observation and verification; and use has been made of it above (p. 570) to shew the antiquity of the rivers and of the mountains (or at least of the land-surface) from which they flow. The negative or destructive operations are much less susceptible of direct proof; and accordingly there are still some who believe that the great gorges and valleys of the mountains are the gaping fissures of the fractured earth. In detail it is perfectly easy to confute this supposition;

[1] Ball: Rec. G. S. I., XI, p. 174.
[2] Mem. G. S. I., XI, p 7.
[3] Q. J. G. S., XXIV, p. 51.

to shew in countless instances that the rocks in the deep gorges of the river-beds are not, and never have been, so fractured; and once the door is closed against this vein of semi-occult hypothesis, a rational interpretation of the forms of denudation, based upon known and measurable modes of action, becomes possible, and a new record is opened to the geologist.

The conditions of this mode of action have never been very systematically formulated, although few natural processes have to work with so simple and axiomatic a rule—that water will not rest unsupported upon a slope, and must flow by the lowest channel of escape. The uncertainties of the problem arise from unknown partial interferences, by ground movements, with the original levels; but of these influences also, evidence should be forthcoming, as is that of the changes which occur normally in any large drainage system, whereby an originally transverse[1] drainage may become by itself more or less converted into main longitudinal channels.

This normal process of formation of river-systems is too well understood to need explanation here[2]; and it is evident that abnormal changes of the drainage lines, by local disturbances of the ground-levels, should also be traceable; though it might not always be easy to assign the exact cause: for example, a small additional tilt of the outer range would have sent the drainage of the old Nepál lake down the longitudinal valley to the south-east; but the gorge of the Bághmati would have remained as a permanent testimony of a former state of things.

We may now indicate the application of these considerations to some features of the Himalayas. The case of the Chináb has been already noticed (p. 562), where it passes by a deep narrow gorge at Riássi through a lofty ridge of palæozoic limestone, surrounded by much softer tertiary rocks, the ground to the north being several thousand feet lower than the crest of the ridge. That gorge not being a fissure—it is tortuous, and the rocks are perfectly continuous and unbroken across the river-bed at both ends—it must have been slowly excavated by the river; and throughout that process the ground to the north must have been higher than the river in the gorge, and so originally higher than the present crest of the ridge. It cannot be asserted that the surface to the north of the ridge was ever higher than it is now; for the disintegration of the tertiary rocks and the erosion of the gorge may have kept pace with the gradual

[1] See note, p. 529.

[2] For an admirable illustration of the process referred to in the text, see a paper by Mr. Jukes, "On the mode of Formation of some of the River Valleys in the south of Ireland," Q. J. G. S., XVIII, p. 378, 1862.

elevation of the whole ground; while the resistance of the older rocks preserved them to be elevated to their present position. Or, the ridge being distinctly a case of locally greater upheaval, the erosion of the gorge, on the primitive course of the river, must have kept pace with that special elevation; for otherwise the stream would have made a new channel through the softer rocks. But the fact remains absolute, that within the lifetime of this river, the rocks forming the crest of this ridge must have been lower than the ground to the north.

More important, though less striking, are the cases to be found in the higher mountains. That all the great Himalayan rivers have their sources well to the north of the line of greatest elevation in the main snowy range, has for long been a familiar fact; and also that the three largest of them—the Indus, the Sutlej, and the Sangpo or Brahmaputra—run for great distances in longitudinal courses within the mountains, so as almost to draw their head-waters from a common source in a middle position. We have no direct observations upon the gorges of these rivers in the high mountains, as to whether they can be regarded as lines of fissure; but all the collateral evidence is decidedly against that assumption. We may at least glance at the question as if these river-courses had been selected under the simple conditions that govern formation by erosion.

We cannot here assert positively, as in the case of the Riássi gorge, that the river valleys through the snowy range were originally filled by a mass of rock, continuous with the mountain crest on either side; although the probability is that they were very approximately so; and it is quite certain that prodigious erosion has taken place in those positions through the agency of the rivers. It can then be absolutely asserted (*if we ignore the supposition of original fissures*) that throughout that process of erosion, and at its origin, the whole ground to the north was higher than these transverse drainage lines, through what is now the main mountain range; and, therefore, that this range (as such), at present the most conspicuous feature of the mountains, is of later date than these river channels.

The facts further point to the probability that the present longitudinal character of the Himalayan drainage may have been more or less brought about from an original transverse type, by the normal process of change alluded to in a previous paragraph. The gorges of the greater torrents, the Sutlej and the Indus, are much deeper than those of the other rivers draining through the main range; and they may thus in process of time have intercepted and drawn off the original head-waters of the latter streams, which may have originally drained from beyond the basin of the sedimentary rocks. No doubt the story may have been otherwise, and these longitudinal rivers may have been more or less

aboriginal, through circumstances that are easily imagined; but the question is not beyond the range of evidence; and the fact that the minor rivers have been able to open, or keep open, a passage through what is now a great mountain barrier, is suggestive that for a considerable period they had a larger source of power than now.

These considerations upon the drainage system lend some support to views upon the mountain structure derivable from the rocks. It has been suggested, with some probability, that the great sedimentary series of the Central Himalayas was originally laid down in a continuous basin of deposition, though now broken up into great synclinal basins of disturbance, represented on the north-west by the Zánskár and the Kárákoram areas; also, that the "central gneiss" of the "main range" and the Lower Himalayas has always been an elevated mass relatively to that basin of deposition. Upon these seemingly probable inferences (or assumptions) the gneissic axis of Ladák now dividing these basins of disturbance, and formed in whole or in great part of metamorphic palæozoic rocks, must be considered as the chief and central feature of Himalayan disturbance, and the line upon which the greatest amount of upheaval occurred, whatever elevation it may at any time have attained. The drainage system, at least in the middle region of the mountains (Hundes), strongly suggests that it originated from that central axis of disturbance as a line of relatively greatest elevation; the fact that the drainage took its origin from a watershed somewhere to the north of the present main chain being a certainty.

Two views are compatible with the facts: either the elevation of the whole area was equable, and the original spill from that central crest of upheaval, across what is now the position of greatest elevation, has been maintained simply by erosion, the present less elevation of the central range (Ladák axis) being also a result of denudation, as may well be the case; or, there has been a subsequent special elevation along this line of the present main Himalayan range. In this case, this special upheaval must have been so gradual that the erosion of the passes could keep pace with it; or else these had been for the most part cut down before it set in. The latter supposition, of a partial later elevation of the Himalayan range proper, would help to account for the great lake of Hundes; although the basin itself, as formed by the drainage of the Sutlej, is probably of older date. In the case of the limestone ridge at Riássi, we could shew that such a special marginal upheaval had taken place; for that limestone at no very distant period had formed part of the level bed of the nummulitic sea, and so, at the commencement of the disturbance, must have stood at a lower level than the upper tertiary rocks to the

north of it. The case is different for the gneissic axis of the main range: we have seen reason to think that from very early times it has formed a relatively elevated mass; but we have also (p. 604) shewn reason to suggest that this fact may have led to its special elevation under certain conditions of disturbance by compression.

Summary.—Beyond the fact that a very full sequence of formations has been palæontologically established in the Tibetan regions, there is little to bring forward from this chapter as general results.[1]

(*a*). The relation of the lowest strata of the slate series on the Tibetan side, to the gneiss of the main chain and of the Lower Himalayan area (p. 628), indicates their wide separation in age, and, so far, agrees with the more marked stratigraphical break between that same gneiss and the slate series to the south of it, in the Lower Himalayan area (p. 620); so far confirming the probable equivalence of the two slate series, and establishing this gneiss as a primitive rock in the Himalayan series, forming here a sort of neutral block in the disturbances that have produced the mountains. It might thus, too, be regarded as having formed here a primitive Himalayan range, from which the quasi-erratics of the Pángi slates were derived (p. 664); and Dr. Waagen in the paper just quoted (see note) makes use of it in this way to account for the contrasting life-conditions of the areas north and south of it, throughout the palæozoic and mesozoic epochs, thus connecting it with the Peninsular rather than with the true Himalayan region. However this may have been in pre-Himalayan times, considerations upon the drainage system have suggested (p. 676) that since eocene, or, at earliest, cretaceous times, it has not always been, as now, the principal crest of Himalayan elevation.

(*b*). The few instances of thinning out of deposits that occur in the mesozoic formations (p. 643), again indicate this Lower Himalayan area as a southern limit of deposition; although in several of the groups there is no symptom of any such limitation (p. 642).

(*c*). The extensive metamorphism of the palæozoic rocks in other positions, especially on the central axis in Ladák, may suggest the opposite condition in those positions—that a greater depression and accumulation of deposits had occurred there; unless that metamorphic state is to be accounted for by the greater compression and upheaval of which those positions have been the *loci*.

[1] For a partial comparative discussion of the palæontological data, we may refer our readers to an essay by Dr. Waagen in the Denkschriften d. Math.-Natuwissenchaftlichen Classe d. K. Ak. d. Wissenschaften. Wien., Vol. XXXVIII, 1878; and Rec. G. S. I. XI, Pt. 4, 1878. This general subject is also treated of in the Introduction.

(*d*). In the central, as in the outer Himalayas, the relations of the tertiary rocks are of chief importance in the history of the mountains; and already some interesting points have been made out. From the Sub-Himalayan sections it was shewn (p. 569) that an eocene land had existed in the Himalayan area. The distribution of the nummulitic deposits in Tibet, so far as accurately known, would independently suggest the same fact: they are totally cut off from connexion with all preceding deposits, and now lie in a compressed trough, chiefly in contact with the metamorphic palæozoic strata, in the very centre of Himalayan disturbance, where presumably the maximum of total upheaval took place (p. 678), *i. e*., including pre-tertiary with post-tertiary elevations. After the cretaceous epoch, a prolonged elevation set in, involving the corresponding denudation of the whole sedimentary series down to the altered palæozoics, and the rise, on adjoining areas, of mountains having a height at least equalling the thickness of the mesozoic series; this position of maximum upheaval, on the Ladák axis, corresponding with that of greatest denudation, where subsequently the eocene deposits were accumulated. It is, of course, clear that at the beginning of the tertiaries, these depressions of the Himalayan area were still, or again, at the sea-level. This preliminary, pre-tertiary stage of Himalayan elevation, of the whole area we now speak of as Himalayan, would very closely correspond with the period of the Deccan trap of the Peninsula.

(*e*). It is a point of very great interest to ascertain how far, if at all, that pre-tertiary elevation of the Himalayan axis was accompanied by the disturbance of contortion which is the special character of the Himalayan mountains (p. 634). No fact is better established in the Sub-Himalayan zone, at two distinct points (p. 569), than that the special disturbance of the silurian slates there is altogether post-eocene, subsequent to the elevation of the central area, as just described. Can it have been so also in the central region? If so, the history of the mountains would be brought within a narrow compass: a broad, unbroken, pre-tertiary elevation of the area (clause *d*), followed in middle tertiary times by a break-up and compression into flexures. If not, if the plication also of the central region preceded the deposition of the Indus tertiaries, a pretertiary act of special Himalayan disturbance would be marked off, distinct from that which produced such great effects on the southern border of the mountains. It is certain that extensive crushing and folding of the central region, with irruption, took place after the Indus tertiaries; but there is no observation as to whether in degree, or by discordance, it can be distinguished from an earlier contortion; and thus it

is still an open question whether the special Himalayan disturbance is altogether post-eocene.

(*f*). There remains the important question, how far the rising of the mountains to their present elevation coincided with the act, or acts, of plication (*écrasement*, "mashing;" *see* note, p. 667)? It is quite clear that the special Himalayan contortion had been practically completed, and the mountains had very approximately assumed their present sculpture, when the undisturbed strata of the Hundes basin were deposited (pp. 651-670). If those deposits are Siwalik, it would be plain that the very considerable contortion of the latest Siwaliks of the Sub-Himalayan zone took place, as has been suggested from other facts (p. 570), long after the principal contortion of the mountains, as a whole, and after they had approximately assumed their present contours. There remains, however, the very important question of elevation, as distinguished from form and structure: it is strongly objected, that the rhinoceros could not have lived at the present elevation of the Hundes deposits. When the possibilities of this condition are fixed, we may be able to record another, and perhaps the latest, event in the physical history of the mountains—a great continental elevation of the area, without sensible contortion of the rocks, and after the sculpturing of the mountains to very nearly their present shape had been accomplished. Any clear evidence of simple and extensive upheaval, distinct from, and long subsequent to, the chief special plication so characteristic of the mountain region, would be an interesting contribution to the theory of mountain-formation.

CHAPTER XXVIII.

EXTRA-PENINSULAR AREA.

THE ASSAM RANGE.

Area to be described — Formations present — General structure — The Sylhet trap — The cretaceous series : Khási area — Gáro area — Mikir area — The nummulitic series : Khási area — Gáro area — Eastern extension of the nummulitics — The upper tertiaries — The Nága coal-fields.

Area to be described.—The ground to be described in this chapter is a kind of residual area, for which even a name has to be invented. Assam, as known in geography and in the Anglo-Indian vernacular, is the valley of the Brahmaputra, from the Brahmakhund to Dhubri, a direct distance of 420 miles ; and this has been already described in the chapter on post-tertiary deposits (p. 405). The northern border of the valley has also been described in the Himalayan chapters (pp. 545, 618). There remain the hills bounding the valley continuously on the south, and now included in the province of Assam, recently formed into a local government, under a Chief Commissioner. The close connection between the hill tracts and the Assam valley justifies us in speaking of these hills collectively as the Assam Range, in order to use one general term instead of the five or six names now applied to different portions of the hill country, as was explained on page 27. This confusion of names is, however, to a great extent founded on the undecided or contrasting features of the ground, as may be apprehended from the statement that more than half of this range has already been described as structurally belonging to the peninsular area.[1]

The hills formed of these most ancient rocks, and occupied by the Gáro, Khási, Jaintiá, and Mikir tribes, are for the most part low and very irregular on the north side, with numerous outliers in the Lower Assam valley, even close up to the Himalayan border (p. 522). On

[1] For the little we know regarding the gneiss forming the great mass of the hills, extending for 250 miles, between the Dhansiri and the Lower Brahmaputra, we must refer the reader to page 26; and the transition rocks associated with the metamorphics are noticed at page 40.

the south and south-east the metamorphics are everywhere overlapped by very much newer strata, upper secondary and tertiary, which in this position are still undisturbed; and so form plateaus between the deep river gorges, with a high scarped face along a regular line to the south. To the south of this line, the same neozoic strata are greatly disturbed; and consequently form hills of very different outline from that of the adjoining table-lands. This remarkable feature is badly seen in the middle region, that of the Khási and Jaintiá hills, where the alluvial plains of Sylhet reach nearly to the base of the plateau, with only a very narrow intervening outcrop of the disturbed rocks. To the west, in the Gáro country, the fringing zone of low hills is somewhat broader, between the plains in Mymensingh and the crystalline rocks of the Tura ridge. To the east of Jaintiá a complete change takes place rapidly in the relative magnitudes of these contrasting features; the dividing line curves gradually to the north-east, so as to emerge in the Upper Assam valley, near Golághát, on the Dhansiri; while the formations in the zone of disturbance expand enormously in the Nága country, and rise into a range of hills that quite overlooks the crystalline area. In North Cachar this is known as the Barail range, and its prolongation to the north-east, separating Upper Assam from Manipur and Burma, is called the Pátkai range. It is confluent with, and a member of, the Indo-Burmese mountain-system, of which the Barail-Pátkai range may be considered a border zone, near the original margin of the deposits which principally constitute that region of special disturbance.

It is thus plain that the Assam Range is made up of two very distinct portions. Besides its strong petrological resemblance, the characters sustained by the gneissic mass, as an area at least partially, reserved from deposition, and as a neutral block of ground, unaffected by the disturbances that have operated so powerfully in adjoining areas, mark it clearly for affiliation to Peninsular India. For these reasons it has been described in that connexion, and distinguished from the adjoining hills under the title of the Shillong plateau. [1] Thus only the newer formations of the range remain to be noticed. The description must be given in the same disjointed manner as for the Himalayan area, because our information [2] is equally fragmentary in the present case.

[1] Mem. G. S. I., IV, p. (427).

[2] The following papers refer to the ground under description :—

Oldham : Mem. G. S. I., I, p. 99.

Medlicott: Mem. G. S. I., IV, p. (387); VII, p. (151); Rec. G. S. I., VII, p. 58.

Mallet: Mem. G. S. I., XII, Pt. 2.

Godwin-Austen : J. A. S. B., XXXVIII, 1869, Pt. II, p. 1.

Formations present.—The rocks to be described have only been studied with any care in two positions, far apart: one, on the Khási hill section, at Cherra Poonjee, and one in the coal-fields of the Nága hills, in Upper Assam; and although the formations in both are, presumably, on the same general horizon, the petrological differences are so great, that no exact correlation of groups can be attempted. In the former ground the rocks are seen resting upon, and immediately contiguous with, the gneiss, and some very noteworthy variations of composition in the several groups have been observed in this position. The gneiss does not appear near the Nága hill coal-fields, although it may underlie the upper Assam valley at no great distance. The descriptions of these two areas will be given separately; and it is only possible to give the most general designation of the formations as applicable to the whole area, in the following form:

Tertiary series.—An immense thickness of soft sandstones and clays, based upon a nummulitic group, in which limestone is locally in force; coal also occurs.

Cretaceous series.—Sandstones and shales, with local coal basins.

Jurassic (?)—The Sylhet trap, stratified.

General structure.—The leading characters to be exhibited in these formations are—the original termination, either abrupt or gradual, of each against, or upon, the old rocks of the Shillong plateau, clearly marking this as the margin of a great basin of deposition; and, the subsequent disturbance of the whole sedimentary series up to the edge of the crystalline mass, shewing that the latter has been comparatively unaffected by the forces that produced so much contortion in the adjoining ground. It is further of interest to observe that there is a great decrease in the thickness of the sedimentary series from east to west—a fact supporting the conjecture of the original continuity of the gneissic area with that of the Peninsula. It is also of special interest to find a corresponding steady increase of disturbance from west to east, confirming the well-founded opinion of a direct causal relation between the original and induced structural conditions—between the amount of deposition and the degree of disturbance.

In one respect there is a noteworthy discrepancy between the relation of the gneissic mass and the newer stratified series, in the Assam Range and in the Peninsula. In the latter the fringing marine deposits everywhere flatly overlap a very irregular surface of the gneiss: a similar relation is found where the strata rest upon the metamorphics of the Shillong plateau; but in this Shillong ground there is a marked outer line of southern limitation of the older rocks, at many points of which line the

newer strata abut against the older, as mentioned above. It can be seen on the general map, and better still on the small hill-ranges map in the Introduction, that this feature would seem to belong to the Himalayan system, being remarkably parallel to the Eastern Himalayan border in Assam; or even as if it might once have formed a continuation of the middle Himalayan boundary. Such a temporary connexion cannot, of course, annul the more fundamental connexion of the crystalline rocks with those of the Peninsula; but, whatever this seeming Himalayan connexion may mean, it will be shewn that the feature in question is not due to the middle tertiary disturbance, by which the Southern Himalayan border was defined (p. 570), or to the post-tertiary disturbance, of which the Barail-Pátkai range is an effect: although the exposure of the feature is, of course, owing to the disturbance and removal of the covering rocks, it will be shewn that this steep face of old rocks is older than the Sylhet trap, and that it gave its form to the feature of disturbance, instead of the reverse.

This distinctly local cause for a feature of direction having such magnitude as the Barail-Pátkai range, more than 400 miles long (measured to the Brahmaputra), removes, or at least greatly reduces, any difficulty that might have been preconceived regarding this range belonging to the Indo-Burmese, rather than to the Himalayan, system of mountains; although for a considerable distance the two run directly at right angles to each other. The Barail, with its structural continuation westward to the Brahmaputra, may not be strictly a monogenetic component of the meridional ranges of the adjoining area to the south; but all the accessories of disturbance are common to both, as formed of immediately continuous formations in the same basin of deposition. The monoclinal flexure along the edge of the Shillong plateau may have been due to the initial act of depression which culminated in the great waves of compression of the Burmese mountains. These explanations are needed to remove the *primâ facie* impression of the necessary distinctness of the Assam, or at least the Barail-Pátkai range, from those to the south, and its equally apparent relation to the Himalayas: though, indeed, this distinction does not imply much difference; both systems of disturbance are so closely related in age, the Burmese being, perhaps, somewhat the more recent. The Shillong plateau portion of the Assam chain stands equally aloof from both areas of disturbance.

With reference to the parallelism of the Barail-Pátkai and the Himalayan ranges, we may also note the contrasting structural features: in the Sub-Himalayan zone of Assam, as elsewhere, the dominant dip of the rocks is inwards, towards the older rocks of the mountains; whereas the

corresponding tertiary formations of the Barail-Pátkai range, where fully developed, dip as constantly southwards, away from the gneissic mass of the Shillong plateau, and towards the southern basin of disturbance.

The Sylhet trap.—The name of the adjoining district in the plains to the southward has been given to this formation, because of its connexion with the area south of the metamorphic mass of the Shillong plateau. All the other formations to some extent overlap the edge of the crystalline area; but the trap ends abruptly against a steep face of the gneiss. These features are beautifully exposed on the paths and in the deep gorges south of Cherra Poonjee. The inner boundary of the trap is so straight and steep, as seen crossing the separate gorges, that the probability of a faulted junction is at once suggested. It is, however, immediately apparent that any such dislocation must be of very ancient standing; for the cretaceous sandstone passes over the trap in an unbroken semi-arch, being horizontal on the plateau and nearly vertical at the base of the hills. The mode of exposure of the eruptive formation is thus in more or less detached areas in the several river gorges, forming together an inner zone, close under the scarp of the plateau. The width of this band in the Tharia river below Cherra is less than two miles; and the height above the sea at which the trap occurs along the inner boundary with the gneiss váries between 2,000 and 3,000 feet, which may be taken as the minimum local thickness of the formation; for the rivers here are very little above the Sylhet plain, which is nearly at the sea-level.

This trappean formation belongs altogether to the basaltic family, and has a strong likeness to the corresponding rocks of the Rájmahál hills and of the Deccan, already described. Close study might reveal distinctive characters; but there has been neither time nor opportunity for this work of detail. The stratified condition is very well seen; and earthy, ashy beds prevail; but there are many flows of hard basaltic rock, both compact and granular, sometimes with much olivine. No dykes were observed in the trap, except at the junction with the gneiss, a boundary which would thus seem to have been to some extent a line of eruption. At the head of the Lián glen (south-south-east of Cherra), some dykes and veins, with transverse prismatic structure, traverse the bedded trap, and penetrate the crystallines for a short distance. The same may be seen in the Bogapáni. It is, however, plain that the junction with the gneiss is one of original contact: this is well seen below Mámlu, south by west of Cherra, where some 200 feet of the topmost earthy trap beds rest on the metamorphic quartzite forming a short spur at Tárna, close to the general boundary.

As no sedimentary intertrappean beds, with or without fossils, have been discovered in this eruptive formation, we can only guess at its age from its relation to the contiguous rocks. Thus it is evidently much older than cretaceous; for it seems to have undergone both disturbance and denudation before the deposits of that period were laid down upon it. This is well seen in the Tharia river, where the trap-flows have a moderate northerly inclination, and are thus transversely bevelled by the cretaceous sandstone, sloping rapidly to the south. No rock is seen below the trap, except the gneiss; so there is a very wide range for conjecture as to its age. It probably corresponds approximately with the jurassic trap of the Rájmahál hills, 200 miles to the west. In any other direction its nearest known petrological congeners would be the sub-recent volcanic rocks of Burma.

The Sylhet trap has not been observed east of the Tharia river, and no doubt it soon becomes concealed in that direction. It is finely seen in the Jádukáta, the Umblai or Kanchiang of the hill people, 40 miles to the west of Tharia, and under very similar circumstances; but it is not again exposed in the Gáro hills. It would seem as if some greater elevation in the middle region, that of the Khási hills, to which the trap is limited, had brought up this lowest formation of the extra-gneissic area in this position.

The cretaceous series: Khasi area.—It is difficult to give an abridged account of deposits where they are subject to much change, and for particulars of these features we must refer to the original descriptions.[1] In the Tharia river, where the strata have a very high southerly dip, there are about 1,500 feet of cretaceous beds between the Sylhet trap and the nummulitic limestone. The bottom 200 feet, next the trap, are of massive, coarse, felspathic and ochrey sandstone. The only beds seen above this here are dark and pale grey shales, locally nodular, calcareous and ferruginous, with some layers of flaky earthy limestone, and of fine, hard, earthy sandstone. There is a similar section on the Bogapáni, 9 miles to the west, with 43 feet of fine sandstone immediately underlying the nummulitic limestone, and probably representing the Cherra sandstone of the plateau. On the Jádukáta, 20 miles farther west, only the bottom sandstone is seen, but in greater force. Near the base of it here some *Brachiopoda*, *Echinodermata*, and fragments of large *Inocerami* were found, and with these marine fossils numerous pieces of fossil resin, the same as occurs so constantly in the coal of this formation. This is the most westerly point at which marine (or indeed any) fossils have been observed in these deposits.

[1] Mem. G. S. I., I, p. 99, and VII, p (168).

In ascending to the plateau, a very marked change is observed in the character of the rocks; the sandy element prevailing here as markedly as the earthy one did in the lower section to the south. About Mahádeo, on the first ledge above Tharia, a glauconitic sandstone is prominent; probably an expansion of the bottom sandstone already noticed. It is traceable at the same horizon at many points in the cliffs south of Cherra. Marine fossils are locally abundant in it. Above this a fine pale sandstone, frequently with broken fragments of plants and also marine fossils, is a characteristic rock; it is often locally calcareous in a very capricious manner. This band is well seen in the Lángpar spur, above the Mahádeo ledge. Above this is the Cherra sandstone, a coarsish hard rock, about 200 feet thick, which forms the edge of the main scarp, and the broad ledges of bare rocks at the edge of the plateau, under the nummulitic limestone. No fossils have been found in it, but it passes down locally into the lower beds, though often sharply separated from them.

In a small collection of fossils from these rocks, Dr. Stoliczka recognised the following species. The highest fossiliferous band, about 200 feet below the edge of the cliff at Mausmai, a coarse sandy limestone, contains small *Lamellibranchiata*, a *Cellepora*, and echinoderms; a finer rock is principally made up of an *Astrocœnia*, allied to *A. decaphylla*.

From about the middle of the series, above Mahádeo, in a stream under Laisophlang, in a soft, ochreous, glauconitic sandstone these fossils were found :—

Nautilus (*? N. elegans*).
Nautilus, with a central siphon; fragments.
Ammonites planulatus.
Am. dispar.
Am. orbignyanus.
Am. ? pacificus.
Anisoceras indicum.
Anis. sub-compressum.
Baculites, near *B. vagina.*
Alaria papilionacea.
Rostellaria palliata.
Gosavia indica.
Cerithium inauguratum.
Tritonidea requieniana.
Hemifusus cinctus.
Phasianella.
Turritella.
Euspira.
Dentalium.
Janira, near *J. fleuriausiana.*
Exogyra matheroniana.
Spondylus striatus.
Modiola typica.
Cardita orbicularis.
Cardium.
Terebratula, near *T. carnea.*
Hemiaster.
Holaster.
Brissus.
Turbinolia.

The facies of this group rather resembles that of the Utatúr beds of Southern India.

From the well-known fossil locality about 2 miles from Tharia, on the fourth cross-cut taken by the foot-path between the zigzags

of the road, or the first below the Devil's Bridge, the following were named :—

Nautilus lævigatus.	*Gyrodes pansus.*
Baculites vagina.	*Gibbula granulosa.*
Cypræa globulina.	*Nerita divaricata.*
C. pilulosa.	*Euptycha larvata.*
Rostellaria palliata.	*Actæon curculio.*
Alaria tegulata.	*Pecten septemplicatus.*
Alaria glandina.	*Janira quadricostata.*
Lyria crassicostata.	*Gryphæa vesicularis.*
Volutilithes septemcostata.	*Spondylus striatus.*
Tritonidea requieniana.	*Pecten*, near *P. rugosus.*
Latirus reussianus.	*Inoceramus.*
Pseudoliva subcostata.	*Rhynconella compressa.*
Turritella pondicherriensis.	*Terebratula*, sp., probably *T. biplicata* and *T. carnea.*
T. multistriata.	
Mitreola citharina.	*Ananchytes* } several species, but distinct
Euspira lirata.	*Brissus* } from any described.

Nearly all the fossils of this list occur also in the Arialúr group of Southern India, but there are a number of species in the Tharia beds which appear to be peculiar, and most of them new. It may be worth recording that the observer who collected these fossils considered the latter locality to be lower in the series than the former, which would be remarkable, if true, seeing that the Arialúr group is newer than the Utatúr.[1]

On the plateau at Cherra Poonjee, which is only 6 miles from Tharia, the thickness of the cretaceous series is reduced to 600 feet, and ten miles farther north, about Surarim, there is only about 100 feet, and thus it gradually disappears altogether. Its last remnants do not occur on the highest ground; but in depressions, and along the edges of the gorges, which had also been valleys in the cretaceous time, where the softer metamorphic rocks had been eroded, the adjoining higher ground being generally formed of the Shillong quartzite (p. 40). In this way outliers occur for some distance to the north, to near Moflong, 13 miles due north of Cherra.

It is in these little primitive basins on the plateau that the cretaceous coal is found. The station of Shillong was for years supplied from a tiny coal-basin at Maubilarkar, between Surarim and Moflong. The mineral itself has a persistent character throughout the whole cretaceous area: it is remarkable as being less of a true coal than is that of the overlying nummulitic group; the texture is compact and

[1] See Chapter XII.

splintery, with smooth conchoidal fracture, and the coal gives a dull woody sound when struck; it has the additional peculiarity of containing numerous specks and small nests of fossil resin. The abundance of pyrites is a serious defect in it as fuel.

The top member of the series, the Cherra sandstone, seems to be continuous throughout: it was recognised at the foot of the hills on the Bogapáni, and it covers the coal at Maubilarkar. There is more doubt as to the continuous identity of the bottom group. In the lower ground it is separated from the Cherra band by 1,000 feet of earthy strata, while to the north it seems to coalesce with the Cherra band. This statement implies that there is an apparently continuous bottom band throughout: in the low ground, next the Sylhet trap, the coarse bottom sandstone is free from pebbles; but as it rises on to the plateau, and overlies the metamorphics, it becomes coarsely conglomeratic, made up principally of half-worn debris of the Shillong quartzite; and this bottom conglomerate is continuous from the scarp to the most northern outcrop. It has, however, been observed that the matrix at different levels partakes of the character of the corresponding horizon below Cherra; it is sometimes glauconitic, like the Mahádeo sandstone, and farther north it is locally calcareous, like the Lángpar rocks. The carbonaceous element is the most persistent; traces of it occur at the base of the cliff south of Cherra; and we have already mentioned the resin found mixed with marine fossils at the base of the series on the Jádukáta.

Cretaceous series: Garo area.—Immediately west of the Jádukáta, or Umblai, in the Hábiáng Gáro hills, Colonel Godwin-Austen has described[1] the cretaceous formation as made up entirely of sandstone, in which he could find no fossil remains, save indistinct vegetable impressions. Coal of serviceable quality and thickness was observed in many places; and attention is called (*l. c.*, p. 23) to this ground as the most favourable for an attempt to work the seams; as the formation here occurs at the very edge of the plains, within easy reach of water carriage.

From the figured sections in the paper referred to, it would appear that the overlap of the metamorphic rocks by the cretaceous sandstones is more gradual in this position than to the east or to the west.

From about the Jádukáta there is a slightly more northerly trend in the strike of the formations through the Gáro country, and this introduces a considerable expansion of the low fringing hills of upper tertiary strata; so that the line of the gneissic boundary emerges at Singmári, near the middle of the Assam range, where it terminates close to the

[1] J. A. S. B., XXXVIII, Pt. 2, p. 1.

left bank of the Brahmaputra. The importance of finding coal near the great river has led to the examination of the rocks in this neighbourhood.

The whole aspect of the Gáro hills is very different from that of the adjoining Khási country. In the latter the undulating uplands of the plateau are continued on the crystalline area, north of the horizontal sandstones; but the whole of the Gáro country is a maze of hills and valleys, with hardly any level ground, and all at a much lower elevation than the plateau country to the east. The leading feature of the area is a ridge of gneiss, coinciding with the line already indicated as the southern boundary of the metamorphic mass. It culminates in Nokrek, at an elevation of 4,652 feet; but is generally known as the Tura range, from the head-quarter station of the Gáro Hills district. It is important to notice that this ridge is not the watershed: the Sumesari (Soomeysurry) drains a large area to the north, passing through the ridge by a deep gorge above the village of Seju.

To some extent, at least, this contrasting condition of the two areas dates from precretaceous times. Even in the Khási hills the shallow basins of the cretaceous rocks shew a connexion with drainage lines that have been again selected by the present streams; but, on the whole, the surface of junction is more like a general plane of marine denudation. The coal-basins of Rongreng and Dáráng, on the upper Sumesari, north of the Tura range, are much larger and deeper. It will be shewn that they have undergone some special depression in tertiary times; but it is certain that they are original basins, for the cretaceous deposits thin out against the surrounding crystallines, overlapping the coal-seams on all sides. This more distinctly subaërial configuration of the crystalline surface in the Gáro area, at a present much lower elevation than that surface in the Khási country, is confirmatory of the conjecture, suggested by the position of the Sylhet trap, that the latter ground had undergone some relative upheaval.

Other more or less detached basins of cretaceous deposits occur to the west of the Sumesari, in the upper valleys of the Kálu and other streams, draining from north to south of the Tura ridge. West of Tura the crystalline rocks become very much lower, sinking to the level of the Brahmaputra at Singmári; and in this ground the sandstones are continuous across the prolongation of the ridge in many places.

The original relations of the rocks are nowhere better seen than here: the spur on which the station of Tura stands, some 2,000 feet below the crest of the ridge, has a midrib of gneiss, with sandstone on both sides, through which the streams have again excavated their

channels. There is little or no disturbance in this locality; and it is plain that the ridge must have stood as it does now when these sandstones were laid down. Thus it would seem that, at this west end of the Assam range, land and fresh-water accumulations of the cretaceous period had more or less enveloped the gneiss of the Shillong plateau, just as the Gondwána formations had covered up the corresponding rocks at the nearest point of the peninsular area, in the Rájmahál hills.

The earliest notice of coal in this ground (by Mr. James Bedford, Revenue Surveyor, in 1842) was in very shallow basins near the villages of Sálkura, Chámpagiri, and Mirámpura, on the low gneissic plateau south-east of Singmári. The seams are altogether valueless, being only carbonaceous shale, with small strings of resinous coal. It is certain that, so far as the formation is exposed on the western side of the field, there is a very marked decrease of the coaly element, compared with what is seen on the Sumesari, and between that and the Umblai, as described by Colonel Godwin-Austen; yet the rocks are the same throughout: a pale sandstone, in which only traces of plants have been found. A white shale, or pipe-clay, is of more frequent occurrence in the west. The most hopeful point in the enquiry is, perhaps, that the rocks are much more disturbed and exposed in the east than near the Brahmaputra; so that here the coal may lie concealed below the existing outcrops. In this connexion it is important to notice that, while in the Khási section all the beds in the low ground are marine deposits, the coal being confined to high ground at the north margin of the formation, in the Hábiáng Gáro hills, and on the Sumesari, at and below Seju, the coal is equally found to the south of the general gneissic boundary, in what may be called the main basin of the formation. Thus there seems a fair chance of finding it in a like position in the lower valley of the Kálu river.

Cretaceous series: Mikir area.—It is certain that the cretaceous rocks occupy a large space in the Jaintiá hills, where the features of the Khási area are continued for some distance; but we have no observations on that ground. To the east of it the distinctive characters of the formation become much disguised, probably through the substitution of earthy marine deposits for the coal-measure sandstone. The thin bands of hard sandstone, resting on the gneiss, at the falls of the Kopili, south of Nowgong, are supposed to be cretaceous; and the sandy limestone, similarly resting flatly on the gneiss, at the Námbar, near Golághát, is also believed to be of the same formation. In this river, a few miles west of Bor Patár, there is a bed of the typical cretaceous coal; and from the same neighbourhood in the Mikir hills, some white pipe-clay, just like that of Tura, has been sent in for inspection. Thus at its eastern

extremity, on the south-east border, the characters of the Shillong gneissic area, as a very ancient land surface that has undergone little or no disturbance, appear to be maintained.

Nummulitic series: Khasi area.—The northern thinning out of the nummulitic series upon the gneissic plateau is not so clearly seen, at least in the Cherra section, as in the case of the cretaceous rocks, because only remnants of the bottom bands are preserved there; but, on the whole, the evidence is convincing as to the southern expansion of the marine deposits. The nummulitics have not been observed anywhere to rest upon the gneiss, so there is no proof of their having overlapped the cretaceous deposits; but it is presumable that they did so, for the sequence is conformable, or at least parallel and undisturbed, on a rising surface of the metamorphics; and the nummulitics extend close up to the northern boundary, where the cretaceous beds are very thin, near the outcrop of the gneissic rocks.

Immediately to the south-west of the station of Cherra Poonjee there is a small plateau of nummulitic strata. The bottom 80 feet are of limestone, covered by about an equal thickness of sandstone, not markedly different from the underlying cretaceous rock. At about 10 feet above the limestone there is a thick seam of bright coal, the well-known Cherra coal.[1] The limestone rests directly upon the rough surface of the Cherra sandstone, without any sign of intervening denudation; and the bedding is parallel, having a southerly slope of 3°.[2] The fossils from this limestone were determined by Dr. Stoliczka: portions of the rock consist almost entirely of small specimens of *Operculina canalifera*, *Nummulites lucasana*, and *N. ramondi*, both the last species very small; also species of echinoderms, fragments of oysters, *Pecten*, *Cardium salteri*, and fragments of *Natica*, *Cerithium*, *Turritella*, &c.[3]

[1] Oldham: Mem. G. S. I., I., pp. 140 and 185.

[2] This little plateau at Cherra offers a remarkable instance of a form of denudation that is not, perhaps, taken sufficient account of in geological explanations. The scarp is very regular and well defined at many points; but the upper surface of the area, about a square mile in extent, is a chaos of tilted masses of the upper sandstone. This is clearly due to the more or less complete removal by solution of the supporting limestone. A small stream passes under the hill from north to south. The annual rainfall at Cherra exceeds 500 inches. Colonel Godwin-Austen (*l. c.*, p. 21) has described a much larger instance of this form of denudation in the Gáro hills, where a considerable enclosed catchment basin is drained underground.

[3] The fossils described from Eastern Bengal by MM. D'Archiac and Haime in their "Groupe Nummulitique de l'Inde" were all from the Khási hills; but their specimens were so mixed, probably even including fossils from the cretaceous beds, that the value of their identifications is doubtful. As the authors themselves remark—"On voit qu'il y a un certain vague dans les rapports de plusieurs des assises que nous venons d'indiquer:" *l. c.*, p. 177.

Close to the north of the coal hill, the nummulitic beds occur again in equal thickness, under the native town of Cherra Poonjee. The limestone is not seen here; but this may be partly due to concealment. The nummulitic sandstone forms the highest ground of the plateau from Cherra Poonjee to beyond Surarim. Carbonaceous markings are frequent in it; and at Lairangau, 4 miles north of Cherra village, there is a workable seam of coal. It is at about the same height over the cretaceous sandstone as the seam at Cherra; but at Lairangau the underlying beds are all sandstone and shale, except one bottom bed of limestone, resting on the Cherra sandstone. In this limestone bed *Operculina canalifera* and *Nummulites lamarcki* are very common; with these occur a *Trochocyathus*, *Stylocœnia vicaryi*, *Echinolampas sphcroidalis*, a small *Cardita*, *Pecten*, *Natica roualti*, *Keilostoma marginatum*, a *Ziziphinus*, the small *Cerithium hookeri*, casts of a large *Natica*, *Cerithium*, and *Terebellum*.[1]

Under Surarim, only 1 mile from Lairangau, this bottom bed of limestone is wanting; and the carbonaceous sandstones themselves come to an end in a low bluff, 2 miles farther north, near where the road bifurcates. These observations clearly shew the entire replacement of a thick bottom band of marine limestone by a coal-bearing sandstone; or the latter may, perhaps, be more correctly described as overlapping the former.

The same character of the deposits is shewn by a comparison with the section at the foot of the hills. In the Tharia river the nummulitic series is as follows, all with a high southerly dip:—

	Feet.
7. Limestone, coarse, massive, blue	200
6. Sandstone, clear, yellowish, coarsish	100
5. Limestone, fine, compact, blue or pink	200
4. Sandstone, earthy, greenish, ochrey	50
3. Limestone	50
2. Sandstone, yellowish	100
1. Limestone	200
Total	900

In the parallel section on the Bogapáni, below Chela, in the sandstone just over the bottom limestone, there is a coaly layer, which may sufficiently establish the identity of these two bottom bands with those on the plateau above, the marine bed having increased in thickness; and this marine character is here strongly stamped upon the whole series.

These nummulitic limestones form the most prominent features of the low hills at the foot of the scarp along the Khási area, where they

[1] These fossils were named by Dr. Stoliczka.

are in much greater force than elsewhere to east or west. This, as has already been suggested upon other grounds, may be owing to a greater elevation in this position, whereby a deeper zone of the basin of deposition has been exposed to view. Pure limestone is still the chief rock of the group on the eastern confines of the Gáro hills, west of the Umblai, as described by Colonel Godwin-Austen; although the total thickness must be much less than in the Tharia section. In the same ground this observer describes (*l. c.*, pp. 14 and 16) local cases of denudation-unconformity between the limestone and the cretaceous sandstone.

Nummulitic Series: Garo area.—On the Sumesari, however, only 12 miles farther west, a great change is observed. The whole series is exposed; but it contains only one thin band of limestone, about 40 feet thick, resting conformably upon the cretaceous sandstone. Even this limestone is often earthy, nodular, and ochreous, with shaly partings; the purer portion being generally formed of a mass of *Nummulites granulosa*, in various stages of growth. A similar change occurs throughout the formation: there are no clear sandstones; clays and soft earthy sandstones overlie the limestone, and are with difficulty distinguished from the succeeding upper tertiary deposits. This new character is still more pronounced at the west end of the hills. The clear cretaceous sandstone is well exposed in the gorge of the Kálu at Domalgiri below Tura; it is covered by crumbling brown clays, in which occur rusty earthy concretionary layers of nummulitic limestone, the only representative here of the pure rock of the Khási hills; and altogether the formation here strongly resembles the most characteristic beds of the Subáthu group in the North-West Himalayas. No coaly layer has been found in the series in the Gáro area.

The occurrence of remnants of the nummulitic group on the cretaceous sandstones of the interior basins north of the Tura range is a point worthy of attention. In the middle of the Rongreng basin some earthy nummulitic limestone was observed at the level of the river, the cretaceous rocks rising much higher against the surrounding metamorphics. The outcrop is flat and covered; but the presumption is that the local cretaceous group is complete there, and that the actual positions are mainly due to a later depression of these inner basins. There is sufficient independent proof that the crystalline rocks here were affected by the general disturbance, and that the east end of the Tura range must have been squeezed up to a considerable extent. At both ends of the Sumesari gorge, in the Dáráng basin on the north, and at Seju on the south, the cretaceous strata rise nearly vertically against the gneiss, with the beds parallel to the contact; while rocks of the same age occur but little disturbed high on the shoulders of the intervening ridge, the width

at the base being about 4 miles. That there was an original ridge of smaller dimensions in this position is certain; and it seems equally so that the ridge underwent a subsequent special upheaval; and the manner of this upheaval seems to require an actual yielding and protrusion of the gneissic rocks. The disturbance which took effect as a general rise of the Khási area may have been concentrated here in this special crushing upwards of the east end of the Tura range. There is no trace of such an action at the west end, about Tura. Considering the view taken of the original relations of the rocks here, it is rather remarkable that the nummulitics have not been found anywhere in contact with the gneiss; but nothing like a survey of the ground has as yet been attempted.

Eastern extension of the nummulitics.—Having seen the steady increase of purely marine deposits from west to east for 120 miles in the Gáro and Khási areas, it might be expected that the more pelagic formation would be steady for some distance in the same direction, in what is represented as a still-expanding series of deposits. There is no doubt that the total sedimentary series in the Nága hills is much thicker than in the western areas; but it is almost exclusively made up of detrital (clastic) rocks, and it is certain that the increase takes place largely in the upper tertiary formations: the part taken by the lower tertiary (nummulitic) formation in the Nága hills is not known, and its extension in that direction on the map, to include the Upper Assam coal-measures, is still conjectural. The nummulitics of the Khási area no doubt continue for some distance into the Jaintiá country; but their mode of change or of extinction eastwards has not been traced out. Already on the track between Nowgong and Cachar they are so concealed or altered from their familiar aspect in the Khási section, as to have escaped the passing notice of an observer of some experience; and the more detailed examination of the ground in the Assam coal-measures at the north base of the Pátkai, has not revealed any recognisable outcrop of nummulitic strata. The explanation that has been offered of the change to the west may cover this case also: that a special elevation of the Khási area has there brought to the surface a deeper zone of deposits in this great continuous basin of deposition.

The upper tertiaries.—It was said above that at the west of the Gáro hills the earthy nummulitics pass up, without marked change, into the soft upper tertiary strata. There is at first a moderate southerly dip; but the strata become nearly horizontal as they recede from the gneissic mass; so that this section on the Brahmaputra is the most obscure of any in the whole range; the hills are much lower than elsewhere, and the tertiary series must have here a minimum thickness, even if the

whole of it is exposed. Yet the only distinct information we possess as to the horizon of these newer rocks is from this ground. In 1821 Mr. Colebrooke read to the Geological Society of London[1] some observations on these rocks by Mr. David Scott, then Commissioner of Cooch Behar. In those days the Brahmaputra flowed at the foot of the hills, and at one spot on the left bank Mr. Scott found some fossils. The exact locality is not given, but it was somewhere between the Kálu and Mahendraganj (or Karibári), probably nearer the latter place; so the position in the series is not known; but it seems certain that the bed belonged to the rocks of the hills, not to the "old alluvium;" for it is described as at the foot of a small hill, rising about 20 feet over the general elevation. The fossils were a strange mixture of marine with land and fresh-water forms; and amongst them Mr. Pentland described[2] the teeth of *Anthracotherium (Chæromeryx) silistrense*, a species that has been recently found in the Manchar (upper miocene) beds of Sind.[3]

The change of character that is so marked in the cretaceous and nummulitic deposits from west to east has not been observed in the upper tertiaries: there certainly can be no striking feature of this kind. A massive soft greenish sandstone is the most prominent rock; it is somewhat like the common Siwalik rock, but more earthy and of darker hue, and the associated beds are mostly grey shales, unlike the brown and ochrey clays of the Sub-Himalayan series; and the fossils above mentioned shew that even at this western end of the range the deposits are, in part at least, marine. In Mr. Scott's notes of the section on the Brahmaputra, local contortions are noticed, and this condition increases eastwards. On the Sumesari, where the tertiary zone is 14 miles wide, nearly 60 miles from the great river, the state of disturbance is still only partial[4]: at the southern edge of the hills the dip is 40° to the south, in very new-looking strata; there is then a broad band, in which the beds are flatly undulating; they then rise again with a steady and increasing southerly dip. The form of these outer, partial lines of disturbance is that of normal flexures, with the axis-plane sloping northwards, towards the gneissic mass at the edge of the basin (note, p. 528). In the inner half of the section there are two lines of compressed contortion, with intervening bands of nearly horizontal beds. In this more advanced state of compression the features suggest that the flexures had not been thrust over from the north, but from the south, as the reversed fault seems to have

[1] Trans. G. S., Ser. 2, vol. I, p. 132.
[2] Trans. G. S., Ser. 2, II, p. 393.
[3] Rec. G. S. I., X, p. 77.
[4] Mem. G. S. I., VII (193).

a southerly underlie, and the upthrow is on the south. Nothing like a general unconformity in the tertiary series was noticed in the section of the Sumesari.

Only 20 miles to the east lies the ground described by Colonel Godwin-Austen on the confines of the Gáro and Khási areas, where the upper tertiary rocks have been almost denuded away from the base of the range, the little that is left of them being nearly vertical. Several peculiarities have already been noticed in this position: the depression, or the gradual rise, of the metamorphic mass, unlike its abrupt southern ending to east and west: here, too, is the transition ground of the prevailing marine type of deposits in both the cretaceous and nummulitic strata, and here a partial unconformity was noticed between these formations. Similar conditions affect the upper tertiaries: this is the only position in the western part of the range where they have been found on the plateau, inside the line of disturbance. The summit of Nongkulang hill (2,070 feet) is formed of rusty sandstones and shales, resting horizontally upon the undisturbed nummulitic limestone. In a collection of fossils from these beds, sent by Colonel Godwin-Austen, Dr. Stoliczka found the genera *Conus*, *Dolium*, *Dentalium*, *Cardita*, *Cardium*, *Tellina*, *Nucula*, *Leda*, *Cucullæa*, and several others; and he remarked that none of the species, so far as recognisable, appeared to be identical with those known from the nummulitic beds of the same district. This fact suggests that these detached beds on the heights may, perhaps, be an overlap of some beds of the series higher than those that seem to be in transitional sequence with the nummulitics in the sections to the west. This view is strengthened by the fact, that Colonel Godwin-Austen observed some cases of local denudation-unconformity between these fossiliferous sandstones and the nummulitic limestone, the strata being still quite parallel.

Along the foot of the plateau in the Khási and Jaintiá areas the disturbed upper tertiary rocks have been almost entirely removed by denudation. East of Jaintiápur they appear again in force, and expand rapidly into the Barail range, which is, so far as known, entirely made up of them, rising steeply from the alluvial valley of Cachar, drained by the Surma, or Barák. On the south this valley is very undefined, long lateral valleys running up from it to the south, between the low meridional ridges of the Tipperah and Lushái hills, formed of the same soft upper tertiary rocks, some of which ridges strike up to within ten miles of the east and west Barail range. The Cachar valley seems to be excavated out of what must be the very broken ground where these two conflicting strikes meet. As the Barail curves to the north-east into the strike of

the Pátkai, north of Manipur, the confluence with the ridges from the south takes place more easily.

It is only in the north-east, in the Pátkai, that the range forms the main watershed. The northern drainage of the Barail passes through that range, by the deep gorge of the Jatinga, into Cachar. From the edge of the plateau, immediately over the upper Jatinga valley, the drainage flows to Assam. In this position the edge of the plateau, as constituted of horizontal rocks, does not visibly correspond with a supporting mass of metamorphics. There is here a large area of the North Cachar or West Nága hills formed of the massive upper tertiary sandstone very little disturbed. It would seem that the spill of the drainage took its origin here from the first great monoclinal axis of flexure into the basin of disturbance, the protrusion of the Barail range into its present position along that axis being a slow after-process. It seems not unlikely, too, that this great accumulation of late tertiary strata may be largely formed of early Himalayan debris, from the discharge of the great eastern torrents, the Dihong-Dibong, the Brahmaputra, and others; and that the diversion of these through Assam into Bengal was the result of the crushing together of those deposits in the lines of the Burmese mountain system.

The Assam coal-fields.—Upper and Lower Assam are very neatly defined geologically: the latter as the area between the metamorphic mass of the Shillong plateau and the Himalayas, where the metamorphics appear occasionally as outliers through the alluvium, and probably underlie the whole at no great depth. The most easterly known outcrop of these crystalline rocks, north of the Brahmaputra, is the granitic mass at Tezpur. Upper Assam lies on the north-easterly prolongation of the crystalline area, and commences at the Dhansiri valley, where the sedimentary series lying to the south of the gneiss extends beyond it, in the northern ridges of the Pátkai range, to form the south-east boundary of the upper part of the great valley. The general continuity of this line of outcrop here, with that of the crystalline boundary to the south-west, suggests that the metamorphics may extend for a long way beneath the alluvium of Upper Assam; but this is purely conjectural, and the data are insufficient to discuss it.

It has been already stated that, although these rocks of the Pátkai range are the direct continuation, after an unexamined interval of nearly 200 miles, of the formations already described on the southern margin of the Gáro and Khási hills, the general facies of the sequences are so different, that the two can only be correlated by a connected survey, fossil

evidence also being entirely wanting in the Nága ground. This eastern area must therefore stand by itself for the present. Mr. F. R. Mallet[1] has described the coal-measures in some detail, with the rocks immediately adjoining, for a length of about 100 miles from south of Jorhát. He gives the following classification of the formations :—

4.—The Dehing group (from the river of that name): conglomerates and blue clays with fossil wood; minimum thickness, 400 feet; transitional with No. 3.

3.—Tipam group (from the low range traversed by the Dehing above Jaipur): massive, false-bedded, soft, grey sandstones, with subordinate variegated clays and fossil wood; thickness, 7,000 to 9,000 feet; transitional with No. 2.

2.—The coal-measures: alternating shales, sandstones and coal, with a few thin calcareous layers; thickness more than 2,000 feet.

1.—The Disang group (from the river of that name): grey, fine, hard sandstones overlying splintery grey shales, several thousand feet thick.

General structure.—Although in a general sense the section of the Pátkai may be, as suggested, a continuation of that to the south-west, with a prolongation of the crystalline rocks beneath the Upper Assam valley, very great changes are introduced to the north-east. Instead of finding the lowest rocks at the base of the hills, adjoining the alluvial area, as would be the case on the simple supposition referred to, there is, on the contrary, a nearly continuous belt of upper tertiary rocks outside (north-west of)[2] the main outcrop of the coal-measures and of the Disang group. This feature is due to a great fault that has been traced from end to end of the area, with a steady strike to east-35°-north, and having a great upthrow to the south-east. On both sides of the fault the prevailing dip is towards the crest of the Pátkai.

This fault is the leading structural feature of the field, and it must have a throw of from 10,000 to 15,000 feet; for the outer tertiary rocks dip towards it, and high Tipam, and even Dehing, beds are generally found at the dislocation in contact with the Disang group. The principal coal-fields occur isolated inside the great fault, where, at intervals, the throw is less, or where a loop-fault encloses a section of the measures. Here, too, south of the main fault, the Tipam group is found in force overlying the coal group, and proving the magnitude of the dislocation. Thus the several coal-fields inside the fault are strictly isolated as basins of dislocation. The only position where the coal-measures appear at the base of the Tipam group outside the fault is in the Jaipur field, on the Dehing and the Disang; but they presumably occur all along the margin

[1] Mem. G. S. I., XII, p. (269).

[2] See note, p. 529: the axis of disturbance here is not Himalayan, but that of the Burmese system.

of the alluvium, at an unknown depth: the great thickness of the Tipam group would make the search for the coal very precarious, unless near a known outcrop.

The Disang group.—The three upper groups form a continuous sequence, and the top one is a very late tertiary formation, so the Disang beds must take their place below the continuous series, as at least older than the coal-measures. The Disang boundary is everywhere described as faulted, and the original base of the coal-measures has not anywhere been observed: it is, however, quite probable that the Disang beds also form part of the continuous sequence, for both shales and sandstone are very much like those of the coal-measures; only in the latter these rocks are freely interbedded throughout, and include coal-seams at all levels; whereas in the Disang group the shales, as a whole, underlie the sandstone, and both are without carbonaceous layers. As these contrasting conditions obtain in contiguous areas, it is impossible the groups can be the same; and the Disang is certainly the older.

The type section of the group is taken from the Disang, south of the Tipam range, no coal-measures being exposed along the great fault for many miles on either side; but similar rocks occur to the south of the coal-measures, in the Mákum field, to the east, and in the Názira field, to the west.

The coal-measures.—Three principal fields have been described. In the Jaipur field the measures crop up with a high dip along a narrow band at the north base of the Tipam range for about 20 miles, when they are covered over in both directions by the alluvium. East of the gorge of the Dehing, at Jaipur, the Tipam range comes to an end, and the alluvium passes behind it, up to the edge of the Mákum field, along the main fault. This is the most extensive of the Assam coal-fields: to the south-west its exact limit is not known, but it is certainly cut out before reaching the Disang; to the north-east it extends beyond the limits of exploration, into the Singpho country. The Názira field occurs along the great fault, on the Dikhu and Saffrai rivers, for a length of about 16 miles. In the former position the outer hills of the Tipam rocks intervene between the plain and the coal rocks; but on the Saffrai the ground is more open, and the coal-field moreaccessible. Farther to the south-west there are small outcrops of the coal-measures south of the fault, on the Jánji and Disai rivers; but here the outer range of Tipam rocks is very broad, and the coal proportionately difficult of access.

For detailed information regarding these fields and the coal, we must refer to Mr. Mallet's memoir.[1] The measures are very much alike in all;

[1] Mem. G. S. I., XII, Pt. 2.

seams of less than a yard in thickness are very numerous in some sections, and not unfrequently the coal beds attain much greater dimensions. In the Námdáng, south of Rongreng in the Mákum field, there is a seam 100 feet thick, containing at least 75 feet of solid coal; and some very large seams have been traced for more than a mile without diminution. The sandstones and shales often contain nodules and layers of clay-ironstone. Earthy and ferruginous limestone occurs sparingly in thin concretionary bands, also some layers of hard tough magnesian limestone. The coal-measure shales decompose into a very tenaceous blue clay, differing in this respect from the Disang shales, which are more clunchy.

On the interesting question of the age of these very important and extensive coal-measures, there is little evidence for opinion; and that little suggests a middle tertiary horizon. The coal itself is a true coal of superior quality, not lignite, as is attested by its composition.

	Fixed carbon.	Volatile matter.	Ash.
Average composition of 27 Assam coals .	60·0	36·2	3·8
Ditto of 17 Raniganj coals .	51·1	32·6	16·3

It is not unlike the nummulitic coal of the Khási hills, and quite unlike the cretaceous coal, which maintains its peculiar characteristics into close proximity to the Assam fields. The only fossils found in the seams are bad impressions of dicotyledonous leaves; and no trace of animal life has been seen in any of the associated rocks. The strongest point in the argument is the closely transitional relation between the measures and the Tipam sandstone, which is a very typical representative of the Siwalik rock, and almost undoubtedly belongs to that upper tertiary period. In the Khási hills, and again in the Punjab, the nummulitic coal occurs near the very base of the formation: in the Tharia section (p. 694) there are about 1,000 feet of marine nummulitics above the coal bed. If the Upper Assam coal-measures are nummulitic at all, they would seem to belong to the upper limits of the formation.

Tipam and Dehing groups.—We might without much risk speak of these as Lower and Upper Siwaliks; for in very many respects they correspond with those Sub-Himalayan formations as seen on the north side of the alluvial valley; and it is by no means improbable that the two may yet be traced into actual continuity through the wild unexplored country at the head of the valley. The greenish grey (pepper-and-salt) sandstone of the Tipam range undoubtedly alternates with the top beds of the coal-measures; but the shaly beds rapidly cease, and the sandstone becomes very massive. Some coaly partings were also observed well up in the Tipam group; and fossil wood, whether silicified or semi-

carbonised, sometimes in very large blocks, is common throughout this great sandstone formation, as well as in the upper conglomeratic beds.

The upper (Dehing) group is less like the corresponding group of the Siwaliks than is the Tipam sandstone; and two points are noteworthy in it. Some of the bottom beds are coal-conglomerates, made up almost exclusively of rolled fragments of coal, presumably of the coal-seams underlying the Tipam group. This peculiar conglomerate has been observed at great distances apart, at the top of the Tipam sandstone, along the main fault. The ordinary conglomerates of the group also are composed of well-rolled pebbles of fine hard sandstone, identical in appearance with the Disang sandstone. The beds associated with these conglomerates are blue sandy clays, not like the brown and red clays of the top Siwaliks, at least of North-Western India. The facts altogether seem to suggest that these top beds are of very late date; and that the great disturbances now displayed in these formations may be to a great extent older than the deposits which seem to have taken full part in them, as was suggested in some of the sections in the Sub-Himalayas of Kángra (p. 554). But until the rocks at the head of the Assam valley have been studied, it will be impossible to offer any explanation of the general features of this region.

CHAPTER XXIX.

EXTRA-PENINSULAR AREA.

BURMA.

Area and physical geography — Geological data —Rock-groups — Metamorphic rocks — Mergui group — Maulmain group — Axial (triassic) group — Mai-i (Cretaceous) group — Supposed cretaceous coal in Tenasserim — Negrais rocks — Serpentine — Nummulitic group — Arakan — Coal-bearing rocks of Tenasserim — Pegu group — Newer tertiary beds in Arakan — Pliocene fossil-wood group — Tertiaries of Upper Burma — Extinct volcano of Puppa — Trachyte in South-Western Pegu — Post-tertiary deposits: laterite — Older alluvial sands and gravels — Delta of Irawadi — Littoral concrete of Arakan coast — Mud volcanoes of Rámri, &c. — Islands in the Bay of Bengal — Andamans — Nicobars — Barren Island and Narcondam.

Area and physical geography.—British Burma, consisting of the countries on the eastern side of the Bay of Bengal, north of the tenth parallel of north latitude, comprises three divisions—Arakan, Pegu, and Tenasserim. The first and last of these are mainly composed of narrow strips of territory extending along the coast; the former north, the latter south, of the Irawadi delta. Pegu consists of the lower Irawadi valley, south of the parallel of 19° 30′ north latitude, together with the country between the Irawadi and Sittoung (or Sitang) rivers. Martaban, part of the Tenasserim division, includes a large tract between the Sittoung and Salwin.

The whole region is traversed by hill ranges, having a general north and south direction, parallel to the coast. All the principal streams have the same general course, which is the strike of the rocks. To the northward, in Arakan, the strike curves to west of north.

The main hill ranges of British Burma are three in number. Commencing to the westward, the ridge running parallel with the coast, and forming the watershed between the Bay of Bengal to the westward, and the Irawadi valley to the east, is known as the *Arakan Yoma.*[1] This range is the southern continuation of the somewhat complicated ranges to the east of Chittagong; it becomes a well-defined ridge of great

[1] *Yo-ma* is a Burmese word signifying backbone.

breadth, but of comparatively moderate height, east of Akyab, and continues steadily to Cape Negrais. To the northward the general height of the watershed is about 3,000 to 4,000 feet, some peaks rising to as much as 5,000; but to the southward the elevation is much less. This range is the boundary between Pegu and Arakan.

East of the Irawadi valley, and forming the water-parting between that river and the Sittoung, is another range, known as the *Pegu Yoma*, terminating to the southward, close to Rangoon, and extending northward for some distance beyond the British frontier. The maximum elevation of this Yoma is about 2,000 feet, and is attained near the southern extremity, in latitude 17° 55′; thence northward to the frontier the height of the watershed varies from 800 to 1,200 feet.

The whole of the mountains east of the Sittoung must be classed with those of the Tenasserim provinces as parts of one great range, greatly exceeding the Arakan and Pegu Yomas in elevation, and distinguished from both by being mainly composed of metamorphic rocks. To the northward this range, which appears to have no general and distinctive name, is connected with the gneissic ridges and plateaus of Upper Burma; it forms the watershed between the Sittoung and Salwin, the latter river cutting through it near Maulmain (Moulmein), where the strike of the rocks is north-north-west instead of north, and it continues as a number of parallel north and south ranges in the Tenasserim provinces. Towards the southern extremity of British Burma the various parallel ridges coalesce into one general range, which forms the backbone of the Malay Peninsula. The metamorphic hills frequently attain an elevation of 5,000 to 6,000 feet, and some peaks are said to be as much as 7,000 above the sea.

It may be useful to notice that the great rivers of British Burma are the Irawadi and Salwin, both of which rise far to the northward, in Chinese territory. The Sittoung is a much smaller stream, coming from but a short distance north of the British frontier. The Irawadi forms a large delta, but the Salwin flows in a rocky channel almost to its mouth. In Northern Arakan are several rivers of considerable size, the principal being the Koladyne, all running from the northward; and in the Tenasserim provinces, the river Tenasserim has a course of about 150 miles from north to south, before turning westward to run into the sea near Mergui. The general parallelism of all the streams and hill ranges gives an appearance of simplicity to the physical geology of the country; but, owing in a great measure to the prevalence of forest, it has been found extremely difficult to determine the stratigraphy, and very little can be said to be accurately known about the formations occurring.

Geological data.—The province of Pegu has been geologically mapped[1]; but, for the reason mentioned, the classification of the rocks in the hill ranges is by no means satisfactorily settled. The formations along the course of the Irawadi north of the British frontier to beyond Ava have been cursorily examined,[2] as also a tract on the upper Salwin[3]; and the extinct volcano of Puppa, south-west of Pagán, has been visited.[4] Occasional notes, too, have been collected by various travellers in other parts of Upper Burma. A few visits have been made to parts of Southern Arakan in the neighbourhood of Pegu, and to the islands of Rámri and Cheduba,[5] the southernmost part of Arakan being included in Mr. Theobald's map of Pegu, but the northern portion of the division is geologically unknown. All that can be said is, that the formations are probably similar to those of the Arakan Yoma, as the same beds appear to extend northward into the Assam hills. Tenasserim is similarly most imperfectly known, the neighbourhood of Maulmain, and a few localities to the southward, being the only parts of which any account exists.[6]

Rock-groups.—The following are the groups in which the rocks found in Burma have been arranged, with their approximate geological position. It should be repeated that, owing to the very great difficulties in the way of a geological exploration of the country, the sub-divisions are by no means so well defined as in the Peninsula of India. The fossils found have not been compared and described; and until this has been done, it is impossible to feel sure that portions of different groups have not, in some cases, been included in one sub-division.

Name.	*Rocks.*	*Supposed geological age.*
I. NEWER ALLUVIUM, &c.	Blown sand, littoral concrete, regur, and recent alluvial deposits.	*Recent.*
II. OLDER ALLUVIUM	Sand and gravels of the older river alluvium, laterite, &c.	*Post-tertiary.*
III. FOSSIL-WOOD GROUP	Sand, gravels, &c., with silicified wood and bones of *Mammalia.*	*Pliocene.*

[1] Theobald: Mem. G. S. I., X, pp. (189)—(359). Some earlier notices appeared in the Records of the Geological Survey of India, but all details were incorporated in the Memoir quoted.

[2] Oldham: Yule's Mission to the Court of Ava, Appendix, pp. 309—351.

[3] By Mr. Fedden.

[4] J. A. S. B., 1862, XXXI, p. 215.

[5] Mallet: Rec. G. S. I., XI, pp. 188—223.

[6] Oldham: Selections from the Records of the Government of India, Home Department, No. X, pp. 31—67.

	Name.	*Rocks.*	*Supposed geological age.*
IV.	PEGU GROUP	Shales and sandstones, occasionally calcareous; fossils numerous.	*Miocene.*
V.	NUMMULITIC	Shales and sandstone, with some limestone bands containing nummulites, &c.	*Eocene.*
VI.	NEGRAIS ROCKS	Similar, but much hardened, and sub-metamorphic in places.	*Eocene* or *Cretaceous.*
VII.	MAI-I GROUP	Limestone, sandstone, calcareous shales, &c., with *Ammonites inflatus.*	*Cretaceous.*
VIII.	AXIAL GROUP	Shales, sandstones, &c., more or less altered, and occasionally schistose.	*Triassic.*
IX.	MAULMAIN GROUP	Limestone, reddish sandstone, and shales.	*Carboniferous.*
X.	MERGUI GROUP	Slaty and schistose beds, grits, &c.	?
XI.	METAMORPHIC	Gneiss, mica-slate, &c., with granite veins.	*Azoic.*

INTRUSIVE ERUPTIVE ROCKS.—Serpentine, trachyte, &c.; an extinct volcano in Upper Burma.

Of these various groups, it should be stated at once that the three uppermost constitute the greater portion of the Irawadi valley; that the Pegu Yoma consists entirely of the miocene Pegu group; and that the Arakan Yoma, and the spurs to the eastward and westward of the main range, are chiefly composed of nummulitic, cretaceous, and triassic beds. The carboniferous limestone and its associated beds, together with the Mergui group, are, in British Burma, nearly confined to the Tenasserim provinces; the former extending northward into Martaban, whilst the main area of metamorphic rocks lies to the east of all the other formations. In describing the various beds, it will be best, as usual, to commence with the lowest; the intrusive rocks, however, being noticed with the beds with which they are associated.

Metamorphic rocks.—The Burmese gneissic series consists of more or less granitoid gneiss, hornblendic gneiss, crystalline limestone, quartzite, and schists of various kinds. In many places the gneiss becomes a true granite, and much of the area occupied by the crystalline formations has been described by various observers as composed of granitic rocks. Some of the granitoid portions of the rock weather into remarkable rounded masses,[1] isolated from each other by the decomposition of the intervening rock, and forming huge piles of gigantic boulders, as in Southern

[1] Figures of some extraordinary isolated blocks of this kind, resembling perched erratics, but really due to disintegration, are given by the Rev. C. Parish in his "Notes of a trip up the Salween," J. A. S. B., 1865, XXXIV, Pt. 2, pp. 135, &c., Pl. VI, VII, VIII.

India (Hyderabad, Mysore, &c.) and parts of Western Bengal.[1] Hornblendic gneiss seems less abundant than in the main gneissic area of India, whilst crystalline limestone is of not uncommon occurrence.

So little attention has hitherto been paid to the metamorphic rocks of Burma, that very little is known of the minerals occurring amongst them. That the gneissic formations are metalliferous in places has long been known; gold is obtained, in small quantities, in many of the streams, and tin stone is found in some abundance in parts of the Tenasserim provinces and in Martaban. Lead and silver mines, one of them at least—the famous Bau-dwen-gyee—of very large dimensions and highly productive, exist in the Shan States, north-east of Ava. The most valuable and productive ruby mines known are in the same direction, but nearer to the capital. Chondrodite associated with spinel in crystalline limestone has been found close to Mandalay, the combination of minerals being similar to that occurring in certain localities near New York.

As already mentioned, metamorphic rocks occupy a large, but unexplored, area in Upper Burma: they form all the higher ranges in the neighbourhood of Ava, and extend throughout a great portion of the country, extending thence to the Salwin. Farther to the northward they extend from Bhamô to the neighbourhood of Momein in Yunnan.[2] The Irawadi below Ava turns more to the west, and flows through newer rocks, whilst the crystallines continue to the southward, forming the Red Karen (Karen-ni) country and the hills between the Sittoung and Salwin, and extend into Tenasserim. None occur in Pegu or Arakan, west of the range between the Sittoung and Salwin.

It is impossible to do much more than guess at the relations of the Burmese metamorphic rocks to those of the Indian Peninsula; but the gneissic rocks of Burma have more resemblance to those of Peninsular India than to the crystalline formations of the Himalayas.

Mergui group.—Resting upon the metamorphic rocks in the southern portion of the Tenasserim provinces, there is a great accumulation of pseudo-porphyritic sedimentary beds, the principal feature of which is derived from imbedded crystalline fragments of felspar. The rock in its normal form is earthy, but highly indurated; it passes, on the one hand, into slaty masses without the conspicuous felspar fragments, and on the other into grits and conglomerates. With these grits, and resting upon them, are dark-coloured earthy beds, finely laminated, with hard quartzose grits. These rocks cannot be less than 9,000 feet in

[1] A form of "dome gneiss;" see *ante*, p. 20.

[2] Anderson: Report on the Expedition to Western Yunnan, Map.

thickness, and in places they must be 11,000 or 12,000. They have only been noticed hitherto near Mergui, and nothing is known of their relations.

Maulmain group.—The beds of the last group in the Tenasserim valley are succeeded, in ascending order, by hard sandstones, often in thin and massive layers, with thin earthy partings, sometimes in fine laminæ; the prevailing colour is a reddish tint, and some of the layers are calcareous. Some of the more soft and earthy beds contain marine fossils. Over these sandstones occur grey shaly beds, also sometimes calcareous and fossiliferous, with occasional beds of dark sandstone; then come 150 to 200 feet of fine soft sandstone, thinly bedded with grey and pinkish shaly layers intercalated; and upon these, again, hard thick limestone. The fossils found are unmistakably of carboniferous age, *Spirifer* and *Productus* being the commonest forms; but the species have not been determined, and it is rare to obtain specimens in a state suitable for identification.

The thickness of the Maulmain group, exclusive of the limestone, is estimated at about 5,000 feet, and the limestone itself near Maulmain is 1,100 feet thick.

Near Maulmain the limestone is extremely conspicuous, and forms large hills and ranges, extending far to the south-south-east up the valley of the Ataran and Zami. The same rock occurs east of the Salwin, but it does not extend far into Martaban, and it is wanting in the Sittoung valley. Farther up the Salwin, however, in Karen-ni, and elsewhere beyond the British frontier, large tracts of limestone occur, probably belonging to the carboniferous series. Limestone is said to abound in the Mergui Archipelago, and may very probably be, in parts at least, identical with that found near Maulmain. Carboniferous limestone is also extensively developed in Sumatra.[1]

Until the fossils are better known, it is impossible to say whether the Maulmain group exactly corresponds to the carboniferous beds of the Himalayas and the Punjab; there can, however, be no question that both are of the same approximate age. The occurrence of marine fossiliferous rocks of the carboniferous period at the two extremities of the extra-peninsular area of British India, and the complete absence of any marine palæozoic fossils within the peninsular region, afford perhaps one of the most striking illustrations of the great divergence between the geological history of Peninsular India and that of the surrounding countries.

[1] Geol. Mag., Dec. II, Vol. II, p. 478.

Axial (triassic) group.—There is manifestly a great break between the rocks already noticed and the mesozoic formations of Burma; the older beds are found in a distinct area to the eastward, and are associated with metamorphic rocks, whilst the triassic beds are only known to occur west of the Irawadi, and are connected by stratigraphy and position with the newer rocks of the Arakan Yoma range. This range, although of no great height, forms an excessively broad belt of uninhabited forest-clad hills, only traversed by a single road and by a few difficult paths at wide intervals, and it is, in general, absolutely inaccessible, except along the tortuous beds of streams. Anything like satisfactory geological surveying becomes almost impossible in such a region, unless some well-marked and prominent beds occur to afford a clue to the stratigraphy, or fossiliferous belts are numerous. In the Arakan range neither is the case; the rocks of the main range consist of rather hard sandstones and shales, greatly squeezed, contorted and broken, traversed by numerous small veins of quartz, often slaty, and sometimes schistose; but there is a marked deficiency of any conspicuous strata. The few bands of limestone which occur are thin, isolated, and as a rule unfossiliferous. The rocks on the western, or Arakan, side of the range appear, on the whole, less altered than those on the eastern, or Pegu, slope; and on the outer spurs, on both sides, unaltered nummulitic rocks appear throughout a great part of the area, although not continuously.

The crushed, hardened, and somewhat altered rocks of the Arakan Yoma were originally separated by Mr. Theobald from the newer-looking nummulitics under the name of "axials," and considered as comprising the oldest tertiary beds and their immediate predecessors in the series. Although there is a well-marked difference between the nummulitic beds and the "axials," there is no distinct break between them; the two present an appearance of conformity where they are not faulted against each other, and it is far from clear that some of the axials are not merely nummulitic strata, greatly crushed and contorted. But subsequently to the preliminary examination of the area, a cretaceous ammonite was found in Arakan; and amongst some rather obscure fossils discovered near the frontier of British and Native Burma, west of Thayetmyo, were a few specimens referred by Dr. Stoliczka to the typically upper triassic *Halobia lommeli* (Pl. II, fig. 5). It became, therefore, necessary to distinguish both triassic and cretaceous beds amongst the axial rocks of the Arakan range.

To the former has been referred a series of hard sandstones and shales, with grits and conglomerates, and a few bands of impure limestone, which form the crest of the Arakan range at the frontier, and extend to the

southward, nearly to the parallel of Prome. The only characteristic beds are some white-speckled grits, interbedded with shales and sandstones, and attaining a thickness of 1,300 feet, in the Lhowa stream, 35 miles west of Thayetmyo; a band of dark-blue shale with conglomerate, part of which is calcareous, 33 feet thick, below the grits; and some thick-bedded shales, passing into massive sandy shales, with hard nodules interspersed, attaining a thickness of 110 feet, and containing a *Cardita* and some undetermined *Gasteropoda*. The calcareous conglomerate passes into a rubbly limestone, and appears identical with the beds containing *Halobia lommeli*. To the northward a band of limestone, much thicker and purer than that of the Lhowa stream, has been traced in several places. The speckled grits and conglomerates are, however, more conspicuous and more characteristic, and it is mainly by means of them that the area of supposed triassic beds has been mapped.

The whole thickness of the triassic group appears to be rather less than 6,000 feet, the characteristic beds just noticed being near, but not at the base of the group. To the eastward these beds are in contact with nummulitic strata, the boundary having the appearance of a fault; to the westward it is believed that cretaceous beds come in, but the country is difficult of access, and has not been surveyed. The area occupied within the limits of British Burma is elongately triangular, broadest at the frontier, where it extends for 15 miles from east to west, and terminating in a point to the southward, west by north of Prome.

A few outbursts of serpentine occur within the limits assigned to the triassic group. As these intrusive masses differ in no way from some occurring farther south, amongst the rocks of the Negrais group, it will be best to notice all the cases of serpentine intrusion together.

Mai-i (Cretaceous) group.—The existence of cretaceous beds in the Arakan Yoma, like the occurrence of triassic strata, is only shewn by the discovery of one species of mollusk in a single locality in Arakan; the species found, *Ammonites inflatus*, is a characteristic cenomanian cephalopod, common in the Utatúr beds of Southern India. The only specimen obtained was picked up in the bed of a stream, and had evidently been derived from some shales in the neighbourhood. No other specimens nor other fossil of any kind could, however, be found.

The spot where this ammonite was found was near Mai-i, in the northern part of the Sandoway district of Arakan.

What may be the extent of the cretaceous beds, and which strata should be referred to this group, are matters on which but little trustworthy information has been obtained. Mr. Theobald is disposed to consider that a peculiar, compact, light cream-coloured argillaceous limestone,

resembling indurated chalk, sometimes speckled from containing sublenticular crystalline particles, belongs to the cretaceous formation ; and this limestone has been traced at intervals from near Mai-i, about 30 miles north of Tongúp (Toungoop), to the neighbourhood of Sandoway, whilst somewhat similar limestone, though not so characteristic, may be traced to Keantali, some 30 miles farther south. The same limestone is found in the western part of Rámri Island. Another peculiar formation is a greyish, rather earthy sandstone, with, in places, a pisolitic structure, due to the presence of small globular concretions of carbonate of lime and iron. The concretions decompose, and leave small holes, which impart to the earthy sandstone the aspect of an amygdaloidal trap. Like the limestone, this peculiar sandstone is traced from Mai-i to near Keantali, a distance of 94 miles; and if, as appears probable, these beds are really cretaceous, for both are closely associated with the shale from which the ammonite had apparently been derived, the rocks of this formation may be considered as extending at least the distance mentioned. To the northward their range is unknown; to the south, they seem to be replaced by the next group, which may, however, in part at least, be simply the same beds, but more altered. The strata ascribed to the cretaceous group are less hardened and metamorphosed than the other rocks of the Arakan Yoma; they are of great thickness, and may include all the beds to the west of the triassic group, and of the main range of the Yoma as far south as Keantali. No rocks which can be referred to the Mai-i group have been detected east of the main Arakan range in Pegu.

Supposed cretaceous coal in Tenasserim.—There is, however, some probability that cretaceous rocks may exist in Tenasserim. On the Lenya river,[1] in the extreme south of the province, a bed of coal occurs, of very laminar structure, and containing numerous small nodules of a resinous mineral like amber. This peculiar association of mineral resin is characteristic of the cretaceous coals in the Assam hills, and it is highly probable that the Tenasserim mineral is of the same age. At the same time no palæontological evidence has been discovered; the rocks associated with the coal are soft clays and sands, having a more recent appearance than those accompanying the other coal-seams of the Tenasserim provinces; and these other seams are, it is believed, not older than eocene. The coal occurs as an irregularly developed bed, varying from one to five feet or rather more in thickness, with thin layers of fine jetty coal between bands of hard black shale, and rests upon clay with vegetable remains, also containing patches of jet-coal; thin coal laminæ are also found in the associated strata.

[1] Oldham: Sel. Rec. Govt. India, Home Dept., No. X, p. 48.

Below the rocks, immediately associated with the coal, are fine, whitish, earthy sandstones and indurated clay, passing into marl, with some conglomerates. Above the coal is a series of soft muddy sandstones, clays, marls, conglomerates, and a few seams of carbonaceous matter. The whole may be 600 feet thick. The dip is considerable, about 35°, and the rocks have undergone disturbance and faulting. Nothing has been ascertained as to the relations of the coal-bearing beds to other formations ; indeed, all that is known of the Lenya river coal is the result of a hurried visit to a locality very difficult of access.

Negrais rocks.—The remainder of the rocks forming the Arakan Yoma are either unfossiliferous, or the few organisms which have been detected, mostly indistinct remains of plants and mollusca, are insufficient to afford any trustworthy indication of age. Some of these rocks appear to be a continuation of the Mai-i group; whilst, on the other hand, it is impossible to draw any definite line of boundary between the hill rocks and the nummulitics of Pegu. In Pegu, away from the base of the hills, comparatively soft, unaltered fossiliferous beds are found, belonging to the older tertiary period; these strata appear to rest upon the hill beds; for, away from the axis of the range, both have, in general, an eastwardly dip. The two rocks contrast strongly, the nummulitics being soft and unchanged, the hill beds hardened, crushed, and in places almost schistose; but it is impossible to find a precise limit to either; the two are never seen in contact; there is no evidence that they are faulted against each other, and there appears to be a belt, often two or three miles wide, of rock in an intermediate condition. On the whole, it appears probable that the rocks of the Arakan Yoma in general comprise representatives, slightly altered, of both cretaceous and nummulitic rocks; but as it has hitherto proved impossible to draw a line between the two, whilst, on the other hand, there is no clear proof that these Arakan Yoma beds are identical with the Pegu nummulitics, it appears best to distinguish the hill rocks by a separate name, and to class them, as Mr. Theobald has proposed, as Negrais rocks. The name is derived from Cape Negrais, the south-western point of Pegu, and the extreme southern termination of the Arakan Yoma.

The Negrais rocks differ in no important particulars from the triassic and cretaceous beds, already noticed, except that they are more altered than the latter. They consist principally of hardened and contorted sandstones and shales, intersected throughout by numerous small veins of quartz and carbonate of lime. Limestone is not of common occurrence; where it is seen, it does not appear generally in regular strata, but in huge detached blocks, imbedded in the shales and sandstones, as if the

latter had yielded without fracture to the pressure which dislocated the limestone. Conglomerates also occur, sometimes passing into breccia.

The alteration of these beds is most capricious and irregular; frequently for a long distance they are apparently unchanged, except in being somewhat hardened; then they become cherty, slaty, or sub-schistose, and cut up by quartz veins. One not uncommon form of alteration is exhibited by the rocks affecting a greenish hue, due to the presence of chlorite, such rocks being generally much cut up by quartz veins. In a few instances, apart from the serpentine intrusions to be mentioned presently, irregular dyke-like masses of either serpentine or a decomposed steatitic rock are found; but this is far from being of frequent occurrence. A more common form of alteration seen along the coast north of Cape Negrais is apparently due to the infiltration of silica in large quantities, and is shewn by the intense, and often abrupt, alteration of beds of sandstone into cherty masses.

No satisfactory classification of these, the main rocks of the Arakan Yoma, has been practicable; they must be of great thickness, but the stratification is too confused, in the absence of any well-defined horizon, for a clear idea as to the succession of different strata to be formed. Some massive sandstones on the Arakan coast north of Cape Negrais may perhaps be high in the series; they are little, if at all, altered, and dip westward at a low angle. They are of a peculiar greenish hue, and comprise subordinate bands of conglomerate, containing fragments of indurated shale and some quartz. It is possible that these sandstones may be nummulitic; but as it is almost certain that some of the Negrais rocks are older tertiary, the separation of the upper beds is useless without further evidence.

Serpentine.—The occurrence of masses of serpentine has already been noticed; the intrusive rock generally occurs as irregularly-shaped bosses of varying dimensions,[1] but, especially north-west of Prome, dykes also occur. The rock is a characteristic dark-coloured serpentine; it frequently becomes a gabbro, and contains bronzite, and it is intersected by veins of gold-coloured chrysotile, or sometimes of carbonate of magnesia. Occasionally it appears to be replaced by a form of greenstone; or possibly the greenstone outbursts may be distinct, although the two rocks occur in the same neighbourhood. The hills formed of serpentine may be distinguished at a distance by their barrenness; they appear to support little except grass and a few bushes; the greenstone hills, on the other hand, are covered with luxuriant forest. In all probability, the serpentine and greenstone outbursts were originally the

[1] None are sufficiently large to be marked on the map issued herewith.

same, or nearly the same, and the former rock has undergone a chemical change.

In the neighbourhood of some of the larger masses of serpentine, the sandstones and shales are converted into greenstone and chloritic schist; but the effect varies, and in some instances the neighbouring rocks appear almost unaltered. It is, however, worthy of notice that, except far to the northward, all the outbursts of serpentine appear confined to the Pegu, or eastern, side of the range; and that, as has already been stated, the rocks on the Pegu side exhibit, as a rule, more alteration than those on the western slopes in Arakan. To the northward, near the northern frontier of Pegu, serpentine occurs on the highest hills of the Yoma, and, in one instance at least, on the western side; but elsewhere all the outbursts detected are not only east of the main range, but near the eastern limit of the hill rocks. Not a single intrusion has been detected in the unaltered nummulitic rocks.

It is unnecessary to describe the distribution of the serpentine masses in any detail. They are principally collected in three groups, the most northern of which consists of the largest mass known, a horse-shoe shaped intrusion, some 5 miles in length, forming Bidoung hill, amongst the triassic rocks, nearly due west of Thayetmyo. Several masses occur north-north-west of Prome, in the southern portion of the triassic area; and one of these, forming a long dyke-like mass, running for about 5 miles along the boundary between nummulitics and trias, appears to alter the triassic rocks, but not the nummulitic beds, although the latter are greatly crushed. Probably, the difference is owing to the boundary between the serpentine and nummulitics being a fault. The third group is west of Henzada, where twenty-one distinct and isolated intrusions occur, scattered over a length of 26 miles from north to south, close to the edge of the unaltered nummulitic area. The largest of these masses is about 3 miles long by perhaps half a mile broad; but the majority are less than a mile in diameter. Besides these principal groups, a few small and unimportant outbursts are found isolated here and there; none, however, are found south of the area west of Henzada.

Nummulitic group.—Beyond the much smaller amount of alteration that they have undergone, and the resulting difference in mineral character from the hill rocks, there is but little to distinguish the nummulitic beds of Pegu from the Mai-i and Negrais rocks, except the more frequent appearance of fossils, and the occasional occurrence of limestone containing nummulites, especially in the higher part of the group. The ordinary beds are sandstones and shales, unaltered, but still frequently hard and compact. The distinction from the Negrais rocks is far from

absolute; the tendency to a passage at the foot of the hills has already been noticed, and there are, in places within the nummulitic area, hills formed of hardened masses, perhaps older than the rocks around, but which have much the appearance of being the same beds, slightly altered.

The main outcrop of the nummulitic rocks extends from north to south throughout the province of Pegu, east of the Arakan hills, and west of the Irawadi river. The beds have a general dip to the eastward; but to the southward it is difficult, if not impossible, to define the base of the formation, on account of the apparent passage, just noticed, from the nummulitic into the Negrais rocks. To the northward, west of Thayetmyo, near the boundary of British territory, the section is better defined, the lowest eocene strata, however, being, to all appearance, faulted against the triassic rocks; so that here, again, it is uncertain whether the bottom beds of the tertiary series are exposed. In the Lhowa stream, 16 miles west by south of Thayetmyo, upwards of 4,000 feet of hard sandstones, mostly grey, and of blue, grey, or yellow shales, are exposed; but throughout all this thickness of beds, no fossil remains have been detected, except a few carbonaceous markings. Apparently at a somewhat higher horizon on the Mahton stream, which joins the Lhowa from the north, there is a great thickness of massive blue shales, of rather a dark indigo-blue in general, but sometimes of lighter colour. These shales cannot be much less than 3,000 feet in thickness; but they are almost as unfossiliferous as the sandstones and shales on the Lhowa, the only organic remains found being some cycloid fish-scales. Above these shales, again, there is a great thickness of sandstones and shales, mostly unfossiliferous, but containing a few layers with Nummulites; and at the top of the whole group is a band of nummulitic limestone, from 10 to 100 feet thick. This limestone, however, is by no means continuous: where it occurs, it seems to be the uppermost band of the group, but frequently it appears to thin out, and in fact to consist of irregular lenticular bands in shale, rather than of an unbroken bed. Denudation may, perhaps, also have removed the limestone in places before the deposition of the next group. Other bands of limestone occur at a lower horizon, but they are more irregular than that at the top of the group.

The whole thickness of the formation must be considerable—probably not less than 10,000 feet; but no estimate of any value can be made, on account of the imperfect manner in which the rocks are seen. In Northern Pegu, west of Thayetmyo, the breadth of the eocene outcrop from east to west is 17 miles; but a few miles to the south the width diminishes, till, west of Prome, it is not more than 6 miles. The

belt again expands in breadth near Thombo and Akouktoung, on the Irawadi, above Myanoung; but the beds in general are very poorly exposed, being covered with gravel and other late deposits. Farther to the southward, west of Myanoung and Henzada, the nummulitic rocks are much concealed by post-tertiary gravels; and from Henzada to Bassein the only rocks seen to the westward of the Irawadi plain are the altered Negrais beds. The nummulitic strata reappear west of Bassein, and continue thence to Cape Negrais; but still the rocks are much concealed by gravel. Throughout the area, however, limestone with nummulites occasionally appears amongst the higher beds of the group; and a peculiar, very fine, white or greenish, argillaceous sandstone, with *Foraminifera*, seen at Purian point, east of the Bassein river, and in Long Island on that river, is also probably one of the uppermost eocene beds. This rock, known as *Andagu-kyouk*, or image stone, is employed by the Burmese for carving into images of Buddha, and is quarried to some extent for that purpose.

It is possible that nummulitic beds may crop out in places amongst the miocene rocks of the Prome district; but the only known exposure of the former in Pegu, apart from the belt just noticed as extending along the eastern side of the Arakan Yoma, is in a small ridge, known as Thondoung, or lime hill, about 5 miles south of Thayetmyo. This ridge consists in great part of nummulitic limestone, resting upon shales and sandstones; and in the latter a promising bed of coal, 4 feet thick, was discovered in 1855, but proved so irregular as to be of no value; the coal thinning out, and passing into a clay with mere laminæ and patches of coaly matter, in the course of a few feet.[1]

Petroleum has been found in a few localities in Pegu within the older tertiary area; and it is probable that when mineral oil occurs in later tertiary beds, it has been derived from the underlying eocene strata. Such, at least, is Mr. Theobald's opinion after surveying the country, and it is in accordance with the geological distribution of petroleum in Assam.

Arakan.—To the west of the Arakan range, limestone with nummulites has been noticed near Keantali, a village on the coast, almost on the 18th parallel of north latitude; and there can be but little doubt that eocene beds extend along the coast for a considerable distance. The islands of Rámri and Cheduba consist of sandstones and shales closely resembling those of Arakan, and doubtless belonging to the same series.[2] These beds are also very similar to the nummulitic rocks of Pegu. A

[1] Oldham: Sel. Rec. Govt. India, Home Dept., No. X, p 99.
[2] Mallet: Rec. G. S. I., XI, p. 191.

few seams of coal have been found, resembling in character the nummulitic coal of Assam; and petroleum is obtained in several places. The limestone on the eastern side of Rámri Island, as already mentioned, resembles that of the Arakan coast near Mai-i and Tongúp, and may, therefore, be cretaceous; but there is no marked character by which the rocks of the island can be divided into two series.

Farther north the eocene beds probably continue, until they join those of Assam; but the intervening country is geologically unknown.

Coal-bearing rocks of Tenasserim.—Although nothing definite is known as to the age of the beds associated with coal in Tenasserim, except that they are in all probability tertiary, there is more likelihood that they belong to the older tertiaries than to the newer, because similar coal-bearing deposits in Assam on the one side, and Sumatra,[1] Java, and Borneo on the other, are known to be of eocene age. It will consequently be best to notice the Tenasserim beds in this place.[2] They have received more attention than the other rocks of Southern Burma, but still they are but imperfectly known.

The tertiary formations of Tenasserim consist of conglomerates, sandstones, soft shales, and beds of coal. The conglomerates are never coarse, the pebbles seldom exceeding a few inches in diameter; the sandstones are fine, gritty, and pebbly clean white quartzose sands, or earthy and of a yellowish tint; the shale beds are of a bluish-green or blackish tint, and very regularly disposed in thin laminæ. The coal is also in thin laminæ, with earthy bands.

These coal-bearing deposits, the total thickness of which nowhere exceeds 900 to 1,000 feet, are never traceable continuously over any extended area. They are found occupying isolated and detached basins in the great north and south valley of the Tenasserim river, between the main dividing range to the eastward separating British Burma from Siam, and the outer ridges to the westward near the sea-coast. The small tracts of tertiary rocks are in all probability of fresh-water origin, and have much the appearance of having been deposited in the small basins they now occupy. The only organic remains found are dicotyledonous leaves and scales and bones of fish.

The most important coal localities known are Thatay-khyoung and Heinlap on the great Tenasserim river, about 6 miles apart. At the former locality there is a workable coal-seam, 7 feet in thickness, including small partings of shale and clay; at the latter the seam is

[1] Geol. Mag., Dec. II, Vol. II, 1875, pp. 481, &c.

[2] This account is taken from Dr. Oldham's report: Sel. Rec. Govt. India, Home Dept., No. X 1856, pp. 34–56.

between 17½ and 18 feet thick. The quality of the coal is fair, the proportion of volatile matter being large, but the percentage of ash is small. At Kaumapying, three-quarters of a mile north of Heinlap, there is a seam of about 8 feet in thickness, but containing much iron pyrites. Some coal also occurs on the Little Tenasserim river; but the only known seam is not more than three feet thick. The Lenya river coal, farther south, has already been shewn to be very possibly of cretaceous age.

Pegu group.—Above the nummulitic formation of Pegu, there is an immense thickness of soft shales and sandstones, often fossiliferous, but almost destitute of any horizon distinguished either by mineralogical characters or by organic remains. The base of this group is assumed to coincide with the band of nummulitic limestone, already mentioned; but there is no clear evidence that this bed is the uppermost rock of the eocene group, and no unconformity has been detected between the nummulitic rocks and the next strata in ascending order. The upper limit of the middle tertiary rocks of Pegu is equally ill defined, there being a gradual passage from clays and sandstones with marine fossils into the gravels and sands with silicified fossil-wood and mammalian bones.

The fact is that, without a thorough knowledge of the fossils, the classification of rocks so obscure and so ill seen as those of Pegu is a simple impossibility; and until the tertiary mollusks, echinoderms, and corals of Southern Asia are better known, it is hopeless to attempt more than a general rough arrangement of the Burmese tertiaries. In the absence of sufficient fossil data for the proper determination of different beds, all that has been attempted at present is to class together all the marine beds of Pegu without nummulites, and at a higher horizon than the nummulitic limestone; and the group thus constituted has been named the "Pegu group" from its forming the greater part of the Pegu Yoma between the Irawadi and Sittoung. There can be no doubt that a portion of this group is of miocene age, and corresponds generally to the Gáj group of Sind[1]; but it is probable that representatives of other formations are included.

The only approach to a sub-division of the Pegu group that has been suggested is the separation of a considerable thickness of soft unfossiliferous blue shales, which near Prome rest upon the upper nummulitic strata, and underlie the typical fossiliferous middle tertiary beds. These shales have been called the "Sitsyahn shales," from a village on the Irawadi, 8½ miles above Prome; whilst the overlying sandstones and shales with fossils are distinguished as "Prome beds," from their occurrence in

[1] See *ante*, p. 463.

the neighbourhood of Prome. The Sitsyahn shales consist of blue clunchy clay, with indistinct bedding, and, except that they are somewhat paler in colour, greatly resemble some of the nummulitic shales. The thickness of the sub-division is about 800 feet, and the beds have been traced for a considerable distance along the upper limit of the nummulitic rocks in the Prome district.

The Prome beds succeed the Sitsyahn shales conformably, and are composed of grey sandstones, occasionally hard, but frequently argillaceous or shaly, hard yellow sandstones, and shales or clays of various colours. A section of about 2,500 feet of these beds is seen opposite Prome on the right bank of the Irawadi, and probably a much greater thickness exists east of the river. One of the most fossiliferous beds is a band of blue clay exposed at Káma on the Irawadi, 18 miles above Prome. The position of this band is high, and, above it, a bed, abounding in *Turritellæ*, and a hard sandstone containing corals belonging to the genus *Cladocera*, are the highest rocks of the group, and mark the passage into the fossil-wood beds.

In one locality, Minet-toung (Myay-net-toung), 24 miles east-south-east of Thayetmyo, a bedded volcanic rock occurs, consisting of greyish trap, interstratified with the rocks of the Pegu group, and, to all appearance, contemporaneous. Nothing has been ascertained as to the source of this igneous formation.

It is almost useless to give any palæontological details. *Foraminifera* and *Echinodermata* are rare, and the mollusca are not, as a rule, very characteristic forms. A sessile cirriped, very common in some beds, closely resembles *Balanus sublævis* of the miocene in Sind. A few small crabs occur; small corals and sharks' teeth are common.

The Pegu group forms nearly the whole of the great range of hills, known as the Pegu Yoma, between the Irawadi and Sittoung, no older rocks being known with any certainty to occur in the country between the two rivers. The area occupied by the middle tertiary beds is very broad to the northward, where it extends from considerably west of the Irawadi to the base of the metamorphic hills east of the Sittoung, and contracts gradually between the alluvial plains of the two rivers to the southward, till it terminates in a long narrow spur at Rangoon. West of the Irawadi, the Pegu group extends to a little below Prome, and some hills on the opposite side of the river below Prome are formed of the same beds. It is, however, not quite certain that no older rocks appear between the Irawadi and Sittoung; for in some beds in Eastern Prome a species of *Pseudodiadema*, a genus of echinoderms with cretaceous affinities, has been found, and a *Terebratula* with a very cretaceous aspect

was obtained near the town of Pegu. In the former case the beds appear to be high in the Pegu group; but owing to the great extent to which the surface of the country is concealed, both by gravel and other alluvial deposits, and by forest, it is most difficult to make out the geology satisfactorily, and lower beds may be brought up to the surface by faults or otherwise. In the case near Pegu the position of the beds is uncertain.

Newer tertiary beds in Arakan.—On the Arakan coast, in latitude 16° 30′ 50″, is a small island known as Kaurangyi (Koranji), composed of calcareous sandstone or earthy limestone, of a very pale brown or cream colour, and containing echinoderms, mollusks, sharks' teeth, and other fossils. The same rock occurs also at Nga-tha-mu on the mainland opposite Kaurangyi Island, but has not been detected elsewhere. Amongst the fossils the most abundant are a species of *Lobophora* (*Echinodiscus*) and an *Echinolampas*, apparently *E. jacquemontii*, one of the commonest fossils of the Gáj group in Sind: the *Echinodiscus* also closely resembles a Gáj species. The bed is somewhat similar to the "miliolite" of Kattywar, and may represent a portion of the Pegu group; but it is perhaps more probably of later date. One of the sharks' teeth, however, closely resembles one found in the Pegu group south of Thayetmyo.

Pliocene fossil-wood group.—The highest member of the tertiary series in Pegu is distinguished by the abundance of silicified dicotyledonous wood, and is the source whence all the fragments of that substance, so abundant in the older and newer alluvial gravels of the Irawadi, are derived. The fossil-wood group is much coarser than the underlying formations, and consists of sands, gravels, and a few beds of clay or shale, all, as a rule, being soft and incoherent; although occasionally hard sandstone or conglomerate bands occur. The group is thus sub-divided: —

a. *Fossil-wood sands.*—Sand, in part gravelly and conglomeratic, characterised by a profusion of concretions of iron peroxide.

b. *Fine silty clay*, with a few small pebbles.

c. *Sands, shales*, and a few conglomerate beds, with a little concretionary iron peroxide.

The lowest bed *c* passes downwards into the marine bands of the Pegu group, and contains, sparingly, rolled fragments of silicified wood, and a few mammalian bones. Some sharks' teeth also occur. The thickness of none of these sub-divisions has been clearly ascertained; but the lower sands must comprise beds some hundreds of feet thick. The fine silty clay does not exceed about 40 feet in thickness. This bed is quite unfossiliferous, neither fossil-wood nor bones having been found

in it, and pebbles are rare, though a few occur. It thus forms a marked band in the group, and contrasts with the beds above and below it.

The upper fossil-wood sands and gravels are by far the most important members of the formation, and it is from them that the greater portion of the silicified wood is derived. This wood occurs in the form of large and small masses, some being trunks of trees 40 or 50 feet long; usually, however, such masses display marks of attrition, as if the tree stems before being silicified had been transported to a distance and rolled. The wood is always, or nearly always, exogenous; a few rolled fragments of endogenous wood found in newer formations being nevertheless, in all probability, originally derived from the present group. The wood is not coniferous; but owing to the very considerable amount of decomposition it had undergone previous to silicification, its nature is difficult to determine. Besides the fossil-wood, another characteristic of this portion of the group is the abundance of concretionary nodules of hydrated iron peroxide; these are in places so numerous as to have furnished a supply of iron-ore for the native furnaces. Mammalian bones are of only local occurrence.

The following is a list of the *Vertebrata*, exclusive of sharks' teeth, hitherto obtained in the Irawadi valley from the beds of the fossil-wood group:—

MAMMALIA.

Ursus, sp.	*Tapirus*, sp.
* *Elephas* (*Stegodon*) *cliftii.*	*Equus*, sp.
* *Mastodon latidens.*	*Hippopotamus* (*Hexaprotodon*) *iravadicus.*
* *M. sivalensis.*	* *Merycopotamus dissimilis.*
Rhinoceros iravadicus.	*Cervus*, sp.
R., sp.	*Vishnutherium iravadicum.*
* *Acerotherium perimense.*	*Bos*, sp.

REPTILIA.[1]

Crocodilus, sp.	*Emys*, sp.
Gharialis, sp.	*Trionyx*, sp.
Testudo, sp.	*Emyda*, sp.
* *Colossochelys atlas.*	

* Those marked with an asterisk are also found in the Siwaliks of the Sub-Himalayas.

It has been shewn[2] in the chapter on the Siwalik fauna that the mammaliferous beds of the Irawadi valley are of approximately the same age

[1] These genera are recorded amongst the Ava specimens in the collection of the Asiatic Society, Falconer, Cat. Fos. Rem. Vert. Mu . As. Soc., 1859, p. 30; but as all the specimens were unlabelled, there is some doubt about the locality.

[2] See *ante*, p. 588.

as the Siwaliks, or pliocene, if the views as to the relations of the Siwalik fauna advocated in the present work be accepted. Silicified wood abounds in places in some of the Siwalik beds of the Punjab and in the Manchhar beds of Sind; but in the Sub-Himalayan Siwaliks remains of trees are carbonised, not silicified, and there is no great mineralogical resemblance between the Siwaliks and the pliocene sands and gravels of Burma. Independently of the fact that the rocks supplying the materials from which the beds have been derived east and west of the Bay of Bengal are probably very distinct, there is some doubt as to the conditions under which the Burmese beds were deposited, owing to the frequent occurrence of sharks' teeth; and it has been suggested that the fossil-wood group may have been, in part at least, marine or estuarine. The silicified wood itself is never bored by xylophagous mollusca (*Teredinidæ or Pholadidæ*); and as in India, at the present day, not only all wood floating on the sea, but all found anywhere in tidal creeks, and even the dead trunks and branches of trees in places flooded by the tide, are riddled by boring mollusks, it is extremely improbable that the wood found in the Burmese pliocene beds can have been immersed for any length of time in salt water; whilst the tree-stems can scarcely have been silicified before being imbedded, as they would have been in that case too heavy to be transported. It is true that the beds containing sharks' teeth are not those in which the fossil-wood is most abundant; but still some fragments of wood occur with the teeth, and mammalian bones are common. The beds generally are much too coarse for estuarine deposits; and if they are marine, it is difficult to understand why no mollusks or echinoderms, &c., occur. On the whole, it is most probable that the fossil-wood beds, like the Siwaliks and Manchhars, are fluviatile or subaërial, deposited by streams and rainwash, and that the sharks inhabited rivers, as some species do at the present day.

But another distinction between the Burmese and Indian pliocene beds requires notice, as it indicates a wide difference in the later geological history of the two countries. The Siwaliks, as has been amply shewn in the chapters relating to the Sub-Himalayan rocks, have been greatly disturbed, turned on end, and compressed by a lateral thrust. The fossil-wood beds of Pegu and Upper Burma exhibit very slight disturbance, and are generally horizontal. It is thus evident that the great changes to which the Sub-Himalayan ranges, and probably a considerable proportion of the Himalayan elevation, are due, did not affect the Irawadi valley, or only affected it very slightly.

The fossil-wood beds in Pegu are evidently the mere remnants of a formation which once occupied a far more extensive area, the former

existence of the beds being shewn by the occurrence in abundance of fragments of silicified wood far beyond the present limits of the group. At present the only country within British territory where the beds still occupy a considerable area is in Northern Prome. These pliocene strata are rather extensively distributed east of the Irawadi, between Prome and the frontier; and some large patches still exist, although much denuded, on the west of the river, in the neighbourhood of Thayetmyo. Judging, however, from the occurrence of the larger blocks of fossil-wood alone, and neglecting the small fragments in the alluvial gravels, the beds of the present group formerly extended far to the southward, probably along the whole eastern side of the Arakan Yoma, and almost certainly as far as Rangoon along the Pegu range. A considerable area in the Sittoung valley, north of Tonghoo, is also occupied by the fossil-wood beds; but no traces of the former existence of this group is found south of the Kaboung stream, which joins the Sittoung from the westward a little below Tonghoo. There is rather more clay associated with the pliocene beds in the Sittoung than in the Irawadi valley; whilst in two small outlying patches, east and north of Tonghoo, the group is represented by a form of laterite containing numerous pebbles.

Tertiaries of Upper Burma.—The Irawadi valley, from the British frontier to the neighbourhood of Ava, where the metamorphic area is entered, consists of the same tertiary rocks as are traversed by the river in Pegu; but the newer beds with mammalian bones and fossil-wood occupy, comparatively, a much larger area than in Pegu. It is uncertain whether any true nummulitic rocks occur in the neighbourhood of the river, or whether all the fossiliferous clays, shales, &c., should be referred to the Pegu miocene group; but the latter is certainly well represented. From the pliocene gravels the majority of the mammalian remains hitherto collected in Burma have been obtained.

About 50 miles above Ava, the river again runs through tertiary rocks, in which, near Thingadau, some coal has been found. The quality is not very good, but some of the seams are from 3 to 5 feet thick. Nothing is known as to the extent of the coal-seams, nor have any fossils been found to shew the age of the beds; but they are probably eocene.

The most important petroleum wells in Burma are at Ye-nán-khyoung, 60 miles north of the British frontier. The age of the rocks has not been ascertained; they contain marine fossils, and probably belong to the Pegu group. The wells are situated on an anticlinal; all the rocks are very soft—too much so for any fissures to remain open in them—and the mineral oil is apparently derived from a porous stratum.

Extinct volcano of Puppa.—About 50 miles north-north-east of Ye-nán-khyoung, and 25 to 30 miles east-south-east of Pagán, both large towns on the Irawadi, the extinct volcano of Puppa[1] rises to a height of about 3,000 feet above the undulating country, composed of pliocene sands and gravels. The mountain has preserved its original form to some extent; but the crater has been greatly broken down by denudation, and the rim completely cut away at one point, where the drainage from the interior has made itself a means of exit. The peak consists of ash breccia; but lava-flows, mostly trachytic, form the lower slopes and the surface around the base of the volcano. Amongst these flows, some consist of a very beautiful porphyry, with crystals of pyroxene.

The horizontal beds of gravels and sands around the base of the volcano contain fossil-wood and ferruginous concretions, and belong apparently to the pliocene fossil-wood group. They are capped by the lava-flows, and contain pumice and volcanic fragments; and in one place a bed of ash breccia was found interstratified with them. It appears highly probable, therefore, that the volcano was active in pliocene times; but it may have continued to emit lava and scoriæ at a later period.

Far to the northward, in Yunnan, in latitude 25°, another extinct volcano has been observed near Momein.[2]

Trachyte in South-western Pegu.—About 4 miles east by north of the village of Byangyee on the Bassein river, 14 miles south of Nga-pu-tau, and 30 miles south of Bassein, a mass of trachyte occurs, about 6 feet in diameter, and known in the neighbourhood as "kyouk-ta-lon." The relations of this mass are obscure, but it may be part of an intrusive pipe vein: there is no reason to suppose that the block can have been transported from a distance. It is remarkable that the spot is only 15 miles east of a straight line from Barren Island, an active volcano in the Bay of Bengal, to Puppa. It is by no means improbable that the Momein volcanic outburst is connected with the same line of vents, and that it is on the prolongation of the great chain of volcanoes traversing the Malay Archipelago, or the Moluccan band of some writers; the idea, so commonly put forward in text-books, that the northern extremity of this volcanic line is to be found in Rámri and Cheduba, being due to a mistaken notion as to the nature of the mud volcanoes in those islands: the real character of the latter outbursts will be explained presently, after a brief notice of the post-tertiary and recent formations of Burma.

[1] J. A. S. B., XXXI, 1862, p. 215.

[2] Anderson: Report on the Expedition to Western Yunnan, pp. 90, 312.

Post-tertiary deposits: laterite.—Here and there, on the edge of the alluvial tracts of the Irawadi and Sittoung rivers in Pegu and Martaban, laterite of the detrital low-level type is found, forming, as usual, a cap to other rocks, and having a very low dip towards the river from the sides of the valleys. The laterite appears to form the basement bed of the post-tertiary gravels and sands; and laterite gravels, apparently derived from the denudation of the massive laterite, are largely dispersed through the older alluvial deposits.

A few patches only of laterite occur in the Myanoung district, west of the Irawadi; but the rock is more common along the western foot of the Pegu Yoma. To the east of that range laterite is generally wanting; but to the east of the Sittoung river there is a well-marked belt of this formation along the base of the metamorphic hills. The lateritic rock here forms a plateau, rising 50 or 60 feet above the alluvium of the Sittoung valley. Some laterite is also found in Tenasserim, whence it extends into the Malay Peninsula.

Older alluvial sands and gravels.—Along the margin of the Irawadi and Sittoung alluvium, there is a broad, but interrupted, belt of undulating ground, clearly distinguished from the flat alluvial plains near the river, both by the greater inequality of its surface and by its more sandy character. This tract is locally known as "Eng-dain," or the country of the Eng tree (*Dipterocarpus grandiflora*); but the same name is naturally applied to the very similar sandy tracts occupied by the pliocene fossil-wood group, so that the popular distinction does not precisely coincide with the geological limits of the formation.

The Eng-dain tract is composed chiefly of gravel, derived in a large measure from the neighbouring hills, but partly from a distance. A portion of the deposits, as on the edge of the Ganges valley,[1] may simply be "bhábar," the detritus washed from the surface of the hills by rain and small streams, and forming a slope at the base of the range; but in Pegu, as in other countries with a heavy rainfall, this slope is inconsiderable, and a great portion of the alluvial gravels are simply stream and river deposits. Similar beds of sand and gravel are found in many places underlying the argillaceous delta deposits of the Irawadi, and are evidently of more ancient origin.

Besides the fringe, of variable width, formed by the gravels along the edge of the older rocks, large tracts of the same older alluvial deposits are found in places isolated in the delta, forming occasionally ground raised to a considerable height above the flat country around. One such tract, about 20 miles long from north-east to south-west, by 10 miles broad,

[1] See *ante*, p. 403.

occurs east of Nga-pu-tau and south of Bassein; another, of about the same dimensions, lies south-west of Rangoon. These areas may be ancient bhángar deposits, or they may be caused by local upheaval.

Delta of Irawadi.—Except in the immediate vicinity of the river channel, there is no important expanse of alluvial deposits in the valleys of the Burmese rivers; the beds of all, immediately above their deltas, are formed in places by older rocks, and there is no such continuous alluvial plain as is found along the course of the Ganges and Indus. Small tracts of alluvium occur, as usual, every here and there; but the wide undulating plains in the neighbourhood of the river in Upper Burma are composed, not of river alluvium, but of the pliocene fossil-wood deposits.

Compared with the Gangetic and Indus deltas, those of the Irawadi and other Burmese rivers convey an idea of imperfection and backwardness, as though the latter were of more modern growth than the former, and had made less progress towards the formation of a great fertile plain. The Salwin cannot be said to have any delta at all; and in the Irawadi delta, as has already been mentioned, elevated tracts, both of rock and of the older alluvial deposits, occur in the neighbourhood of the sea. Considering the size of the river, the Sittoung delta, if the alluvial plain extending to the northward beyond Tonghoo be included, is proportionally more extensive than that of the Irawadi; but still the broad Gulf of Martaban extends into the very mouth of the Sittoung river.

The Irawadi delta[1] extends from the Rangoon river to the Bassein river, and the head of the delta may be placed near Myanoung.[2] The first important distributary—that forming the head of the Bassein river—leaves the main river a little above Henzada; but water overflows in floods some miles above Myanoung, and finds its way to the sea by the Myit-ma-kha Khyoung, the origin of the Rangoon river. The various rivers and creeks of the Irawadi delta are said to be far less liable to change than those of the Ganges and Indus; but it must be remembered that the authentic history of the latter rivers, and especially of the Indus, extends much farther back than does that of the Irawadi. The general surface of the delta near the sea, with the exception of the higher tracts already mentioned, differs but little in elevation from that

[1] Theobald: Rec. G. S. I., III, p. 21.

[2] Mr. Theobald considers Mengyi, 13 miles below Myanoung, the apex of the delta; and taking Purian Point, east of the Bassein river, and Elephant Point, west of the Rangoon river, as the two lateral angles, he estimates the distances from Mengyi to Elephant and Purian Points as 129 and 176 miles respectively, the two points being 137 miles apart. The area of the entire delta would thus be 8,766 miles.

of the great Indian rivers; and Mr. Theobald considers that at least 2,000 square miles must be below the level of high spring-tides. Large marshes or jhils ("*eng*," in Burmese) are found occupying the depressions between the raised banks of the principal streams; and the whole region, especially in the neighbourhood of the sea, consists of a network of tidal creeks. Little appears to be known as to the progress of the delta seaward: judging by the contour of the coast, it would appear that the Irawadi, owing to its far greater size, and perhaps to the larger proportion of silt transported by its waters, had pushed its delta seaward far beyond the Sittoung. The Salwin traverses for the most part an area of hard metamorphic rocks, and probably brings down but little detritus; so that the conversion of the Gulf of Martaban into land, if it is ever to be effected, must depend largely upon the deposits from the Irawadi.

The alluvial plain and delta of the Lower Irawadi consist mainly of a clay [1] very similar to that found in the Gangetic plain, but containing much less lime, and, in consequence, poor in kankar. The colour is generally yellowish-brown, sometimes reddish, owing to the presence of peroxide of iron. The proportion of sand varies, and is, on the whole, greater than in the Gangetic alluvium. A few thin layers of sand occur, interstratified with the clay; and a band of dark-blue or carbonaceous clay, a few inches in thickness, has been noticed in several localities.

The clay, in many places towards the head of the delta, is seen to rest upon pebbly sand, and the latter is frequently found beneath the clay in the delta itself; wells being sunk through the argillaceous surface formation to the porous stratum beneath. In the absence of any borings, however, it is impossible to say what the nature of the beds at a depth below the surface may be; and it is not clear whether the sand is the underlying formation throughout, or whether it is merely intercalated between beds of clay.

On the surface of the clay, in the immediate neighbourhood of the river, deposits of silt and sand are found in some places, and resemble the khádar deposits of the Ganges valley. No extensive area, however, is covered by these sandy beds; they form a narrow belt along the river channel above the influence of the tide, and occupy a rather larger area around Pantanau. The deposits of the Sittoung alluvial plain closely resemble those of the Irawadi.

[1] Mr. Theobald considers this clay marine or estuarine, but no fossils have been found in it; and his main arguments, founded on the similarity between the clays of the Irawadi and Gangetic deltas, are of course favourable to the fluviatile origin of the Irawadi clay, if that of the Ganges be also, as has already been contended (*ante*, p. 393), of fresh-water origin.

Littoral concrete of Arakan coast.—In many places on the Arakan coast, and especially along the course of several of the less sheltered tidal creeks, a more or less compact calcareous sandstone, containing shells and corals of recent species, is found at some elevation above the level of the highest tides. The rock is porous, evidently formed by the cementation of shells, sand, &c., by carbonate of lime; and precisely similar to the littoral concrete of Bombay, Kattywar, &c. As in Western India also, the presence of this calcareous rock on the Arakan coast affords evidence of a rise of land within a geologically recent period.

On the shores of Rámri and Cheduba, the evidence of elevation is very marked, and some details of the amount and date of the latest movements have been recorded.[1] By these accounts it is shewn that the last rise of the land took place about 1760, and varied in amount from 9 to 22 feet, being greatest in the north of Cheduba, and less to the south-east and north-west.

A few sand dunes are found on the Arakan coast, but they are small and unimportant.

Mud volcanoes of Ramri, &c.—The peculiar geological phenomena presented by the so-called "mud volcanoes" of Arakan and Burma deserve a passing notice. The best known vents are those of Membu[2] (Menbo or Memboo) on the Irawadi, 42 miles north of the British frontier, and those of the islands of Rámri and Cheduba on the Arakan coast; a few others are reported, but they are small and isolated, and consist only of temporary outbursts.[3]

The Rámri mud volcanoes are more interesting than the others, since they alone, so far as is known, are subject to paroxysmal eruptions of great violence, and from them alone stones have been ejected and flames emitted. Some of the principal phenomena may be briefly described here. There are about a dozen or rather more vents in Rámri Island itself, more than half that number in Cheduba, and a few in the other

[1] Halsted: J. A. S. B., X, 1841, p. 434; see also Mallet: Rec. G. S. I., XI, p. 190; and Map of Arakan Islands.

[2] For a description of the mud volcanoes of Membu by Dr. Oldham, see Yule's "Narrative of the Mission to the Court of Ava in 1855," p. 339. The Rámri and Cheduba mud volcanoes are described, with full references to earlier accounts, by Mr. Mallet: Rec. G. S. I., XI, p. 188. Figures of the cones are given in both cases. Mr. Mallet's paper was published after page 379 of the present work was printed; hence the omission of a reference.

[3] No "mud volcanoes" are found in the Indian Peninsula or in the Himalayas; but there is one in Assam, and there are some on the Baluchistan coast, west of the British frontier. See for descriptions, Trans. Bom. Geog. Soc., IX, p. cviii; X, p. 154; Stiffe: Q. J. G. S., 1874, p. 50. The details differ in no respect from those of the Rámri vents.

neighbouring islands. Near Kyouk-phyu (Kyauk or Kyouk-phyoo) in Rámri, six occur in a line, within a distance of about a mile and a half, along the summit of a low broad ridge.

Many of the vents consist of truncated cones, built up of the dried mud ejected by outbursts of gas. The crater, filled with mud, more or less liquid or viscid, through which the gas escapes, occupies the top of the conical hillock. The majority, however, of the Rámri "mud volcanoes" consist of mounds composed, on the surface, of angular fragments of rock, and having scattered over them a few small mud cones of trifling height (from a few inches to 8 or 10 feet), with craters at the top. When gas ceases to be emitted from a vent, the mud is rapidly washed away by rain, and a low mound remains, composed of angular fragments of rock, ejected together with the mud; and a similar process accounts for the formation of the mounds. The mounds in Rámri are from 50 to 100 yards in diameter, with a height of from 15 to 30 feet; two of exceptional size, in Cheduba, near Pagoda hill, being 200 and 250 yards across. The cones in which the mud is viscid are very steep, being built up partly of small quantities of mud spurted out by the evolution of gas, so as to form a hard rim round the mud crater, partly of mud poured out from the crater down the slopes through broken portions of the rim.

Besides the gas and mud, a small quantity of petroleum is usually discharged from the vents. The gas consists mainly of marsh gas (light carburetted hydrogen), mixed probably with some of the more volatile hydrocarbons usually associated with petroleum. The mud is simply the grey shale or clay of the tertiary rocks, mixed with water, containing some salt in solution. There is not the slightest connexion with any real volcanic action; no igneous rocks are found, and if some few stones appear to have been subjected to heat, this is due to the occasional ignition of the inflammable gases emitted. The only distinction between "mud volcanoes" and ordinary emissions of marsh gas is, that in the former case the gas traverses a bed capable of being easily mixed with water, so as to form mud; and this, like the water and petroleum, is carried to the surface by the gas. The term "volcano" applied to such phenomena conveys a false idea of the nature of the action.

The association of petroleum with large quantities of marsh gas, and the frequent emission of water, usually saline, and of gas in abundance, from borings for mineral oil, are too well known to require the recapitulation of details. Both the petroleum and the gas are produced during the slow change of woody fibre into lignite and coal, and both products are known to be found in many localities amongst the tertiary

rocks of Extra-Peninsular India and Burma. Not unfrequently both gas and mineral oil issue with water, in the form of a bubbling spring; both water and petroleum being, perhaps, forced to the surface by the pressure of the gas. Whether a spring of this kind forms a "mud volcano" or not, depends evidently on the nature of the beds traversed on the way to the surface. As a rule, the mud in these vents is either of the same temperature as the air, or a little higher; but in the Rámri craters a higher temperature has been recorded after the more violent eruptions.

These paroxysmal eruptions appear to occur at irregular intervals, and are at times very violent; they appear frequently, perhaps usually, to accompany earthquakes; mud and stones are shot out with great force, accompanied by large quantities of inflammable gas, which in many cases takes fire, and lights up the country for miles around. Some of these eruptions of ignited gas have taken place at sea off the coast of Rámri; and in one case a small island was formed near False Island, south of Rámri and south-east of Cheduba; but it was soon washed away again. The ejected stones are in all cases fragments of the tertiary rocks, chiefly shale or sandstone, some of them being from half a cubic foot to a cubic foot in size, and a few larger; but the majority are from half an inch to 5 or 6 inches in diameter. The ignition of the gas is ascribed by Mr. Mallet to frictional electricity,[1] and not to the high temperature at which the various ejecta issue; the fact that the stones and even fragments of lignite thrown out during eruptions are, as a rule, entirely unchanged by heat, proving that the gas is not in a heated state previous to emission. A very few fragments of burnt and reddened shale have been found, and these have probably been calcined by the flaming gas; but they are rare and exceptional.

It should be noticed that even the fiery eruptions of the "mud volcanoes" of Arakan have nothing in common with the igneous outbursts of true volcanoes. In the former, gas emitted at, in all probability, a low temperature, is ignited, or perhaps occasionally exploded, when mixed with atmospheric air, and flame ensues; in the latter red-hot lava and scoriæ are ejected, and the appearance of flame is due either to the high temperature of the substances projected into the air, or to the reflection of masses of flowing lava by condensed vapours or by clouds of volcanic dust.

[1] *l. c.*, p. 202. Mr. Mallet points out that the principle of the hydro-electric machine, in which the production of electricity of high tension is due to the issue of partially condensed steam through small orifices of such form as to produce great friction, is similar to that of violent evolution of gas from such vents as those of Ramri. He also notices the well-known fact that lightning often accompanies volcanic eruptions.

Islands in the Bay of Bengal.—Of the islands in the Bay of Bengal, exclusive of those forming the Mergui Archipelago, which consist of detached fragments of the Tenasserim rocks, and of the geology of which but little is known, the only groups requiring notice are the Andamans and Nicobars, Narcondam and Barren Island.

The Andamans, and probably the Nicobars, are a continuation of the Arakan Yoma, the islands of Preparis and the Cocos being parts of the same line of elevation, and serving to connect the northernmost of the Andaman group with Cape Negrais. The idea expressed in some geological works, that the continuation of the line of summits formed by the Nicobars and Andamans is to be traced in the islands of Cheduba and Rámri, is not quite accurate, as may be seen by examining a good map. To the southward, the same line of elevation may, perhaps, be continued in Sumatra and Java, as the rocks of all these islands present some points of similarity; but no trace of the volcanic band, so conspicuously developed in Java and Sumatra, is known to exist in the Nicobars or Andamans; and the northern extremity of the great series of igneous vents which traverses the Malay Peninsula may probably be found, as already noted, in Barren Island and Narcondam, and perhaps still farther north, in the extinct volcanoes of Upper Burma and Yunnan.

Andaman Islands.—Although there has been a large convict settlement on the Andamans for nearly twenty years, and although the islands have repeatedly been visited by geologists, very little is known of the rocks, except in the neighbourhood of Port Blair, the British station. The islands are for the most part covered with dense, almost impenetrable, forest, and the coasts, owing to coral reefs and rocks, are difficult of access. The only geological information of any importance hitherto published is contained in Mr. S. Kurz's "Report on the Vegetation of the Andaman Islands,"[1] and in a few details given by Mr. Ball[2] of the neighbourhood of Port Blair.

The Archipelago consists of Great Andaman, comprising North, Middle, and South Andaman, and Rutland Island, all separated from each other by narrow straits or inlets; Little Andaman, about 35 miles south of Rutland Island, and numerous small islets. The larger islands are hilly, and consist of ranges having a general direction from north by east to south by west, parallel to the longer diameter of the group and to the line running from the North Andaman, through the Cocos and Preparis, to Cape Negrais. The highest elevation, Saddle Mountain, in North

[1] Published in 1870. A Geological map is given, shewing the nature of the rocks in all places visited by Mr. Kurz.

[2] J. A. S. B., 1870, XXXIX, Pt. 2, p. 231.

Andaman, rises to rather more than 3,000 feet above the sea; Ford Peak on Rutland Island may exceed 2,000; but most of the ridges are lower. Nothing is known of the geology of North Andaman, nor of Little Andaman; but they in all probability consist of the same rocks as the other islands.

The formations of Middle and South Andaman are extremely similar in appearance to the Negrais rocks of the Arakan Yoma, and in all probability belong to the same group. The prevailing rock is sandstone, fine-grained, grey or greenish in colour, and often containing shales intercalated. Traces of coal occur, chiefly in nests, no true seam having been detected.

An indurated chloritic rock of a dark-green colour, rather felspathic, intersected by small veins of quartz and calcite, and containing crystals of quartz and other minerals in small cavities, extends for a considerable distance northwards from Port Blair, and probably the same band reappears in the Middle Andaman. This bed has the appearance of being a greatly altered form of sandstone, and is precisely similar to one of the rocks occurring in the Arakan Yoma. Serpentine and gabbro are found largely developed south of Port Blair and on Rutland Island, and are doubtless intrusive. A "micro-crystalline syenite" was noticed in one locality by Mr. Kurz; it is doubtless a form of the dioritic rock found locally associated with the serpentine in Pegu.

Unlike the Arakan coast and the Nicobar Islands, the Andamans appear recently to have undergone depression.[1] Stumps of dead trees are found in several places in the sea; and although some of these trees grow in the mangrove swamps, others belong to species which grow above the limit of high tides. There are also some records of encroachment by the sea on the coast, since the period of attempts at settlement in the islands towards the end of the last century; but these changes might be due to marine denudation. The evidence afforded by the tree-stumps appears, however, indisputable, and it shews that the movement of sinking must be very recent. No raised coral reefs have been detected, although some bands of conglomerate on the western side of the islands may indicate local elevation; but, on the other hand, the existence in abundance of kitchen-middens,[2] just where they might be expected to occur, close to the coast, appears to indicate that the sinking has been local, or else that the late movement of depression is exceptional.

[1] Kurz: *l. c.*, p. 4.
[2] Stoliczka: Proc. A. S. B., 1870, p. 13.

Nicobar Islands.—The geology of the Nicobars has been described by Danish and Austrian observers, members of the Galathea and Novara Expeditions.[1] The interior of the larger islands has never been examined; but, from observations made on the coast, a fair idea of the general geology has been obtained. There is a vague report of the existence of an active volcano in Great Nicobar, but no traces of recent igneous rocks have been discovered on the island; and although Hochstetter remarks that the highest peak of Great Nicobar has the form of a volcano, he is disinclined to believe that the mountain is really of volcanic origin.

The rocks of the Nicobar Islands, so far as they are known, comprise the following formations:—

1. Recent coral reef formations.
2. Marine deposits, consisting of sandstone, shales and clay.[2]
3. Serpentine and gabbro (intrusive).

Rink considers that there are sedimentary deposits of two ages, exclusive of the raised coral reefs; and he calls the newer "older alluvium," and the older "brown coal formation." The former comprises some argillaceous formations in the northern islands; the latter the sandstones and shales of which the southern islands are chiefly composed. Hochstetter classes all together, and is inclined to refer the whole to the newer tertiaries, and probably to upper miocene.

This view cannot, however, be accepted as conclusive in the case of the sandstones and shales. Ball[3] has pointed out the similarity of these beds to those of the Andamans, where the rocks are in all probability older tertiary or cretaceous; and the association of serpentine and gabbro is a character common to the rocks of the Nicobars, the Andamans, and Arakan. The principal tertiary formations of Sumatra also are known to be of eocene age; and it is highly probable that similar rocks to those of the Sumatran mountains occur in the Nicobar Islands, as the latter appear to be merely a prolongation of the former. With the exception of a few obscure vegetable organisms, no fossils have been found in the Nicobar sandstones and shales.

[1] Rink, Die Nicobarischen Inseln; Kopenhagen 1847: Hochstetter, Reise der Novara; Geologischer Theil, II, pp. 83-112; Vienna, 1866. A translation of the latter by Dr. Stoliczka was printed in the Records of the Geological Survey of India, II, p. 59. The geology of the neighbourhood of Nancowry harbour has also been described by Mr. Ball: J. A. S. B., 1870, XXXIX, Pt. 2, p. 25.

[2] In Rec. G. S. I., II, pp. 64, 65, &c., the German term "mergel" is translated clay-marls. This is incorrect, as the beds in question are free from lime: see Ball, J. A. S. B., 1870, Pt. 2, p. 27.

[3] *l. c.*, p. 27.

If, however, the sandstones and shales of the Southern Nicobars be older tertiary, it is far from improbable that Rink was right in separating the whitish yellow clays of Camorta, Nancowry, and others of the northern islands of the group; and the newer age of these clays is supported by the occurrence in them of detrital serpentine and gabbro fragments; for these igneous rocks are shewn to be of later date than the sandstones and shales, by being intrusive in the latter. At the same time the clays in question are, locally, much disturbed.

The whitish clays of Camorta and Nancowry collected by Rink were found by Ehrenberg to contain *Polycistina* in great abundance, no less than 300 species having been identified from Camorta alone.[1] The species are nearly the same as those composing similar clays in Barbadoes in the West Indies, and are considered as probably of miocene age.

The serpentine appears to be much more largely replaced by gabbro than in the Arakan Yoma, diallage and bronzite being of very common occurrence. These intrusive rocks break through the shales and sandstones, but fragments are associated with the *Polycistina* clays; and consequently the period of the serpentine eruptions, although posterior to the former, was prior to the latter. Serpentine and gabbro are chiefly developed in the northern islands, Teressa, Bompoka, Camorta, and Nancowry; whilst Tillanchang is almost entirely composed of these rocks.

The upraised coral reefs are found on the coasts of all the islands in places; they form a raised flat fringe, a few feet above the sea, and are covered by a forest of cocoanut palms. On Car Nicobar, Bompoka, and several other islands, these coral banks are of great thickness, and are raised 30 or 40 feet above the sea. The formation is clearly the same as the "littoral concrete" of Arakan and Western India, but richer in corals; and the same conclusions as to a recent rise of land are to be drawn from the occurrence of this fringe of sub-recent marine beds. A large collection of *Foraminifera* was made from the raised coral reefs of Car Nicobar by Prof. v. Hochstetter, and described by Dr. Conrad Schwager.[2]

Barren Island and Narcondam.—The last of the Bay of Bengal islands requiring notice differ entirely from all the others, by being, the one certainly, the other in all probability, recent or sub-recent volcanoes.[3] Barren Island has been repeatedly described by various visitors; Narcon-

[1] Monatshefte K. Akad. Wiss., Berlin, 1850, p. 476; Abh. K. Akad. Wiss., Berlin, 1875, p. 116. Numerous recent and sub-recent fresh-water infusoria from the Nicobars are described in the same author's "Microgeologie."

[2] Reise der Novara, Geol. Theil, II, pp. 187–268.

[3] For an account of these two islands, with full references to former descriptions, see Ball, Rec. G. S. I., VI, pp. 81–90.

dam has never been properly examined, and no one appears to have recorded an ascent to the peak.

Barren Island is about $1\frac{3}{4}$ miles in diameter, and nearly 6 miles in circumference, the highest peak being about 1,000 feet above the sea. The island rises from deep water. A high encircling ridge, broken down nearly to the sea-level on the north-west-by-west side, surrounds a central hollow, in the middle of which a cone rises to a height of 950 feet, with a small crater at the top. The whole consists of basaltic lava and ashes, the encircling rim being doubtless the remains of the original cone, after a large portion had been blown off by a violent eruption. The statement in many geological works, that the sea enters the inner basin, within the encircling rim, appears to be due to a misunderstanding of the original description.

This volcano was very active at the close of the last and beginning of the present century; of late years it is not certain that any eruptions have been recorded.

Narcondam, like Barren Island, rises abruptly from the deep sea to a height of about 1,300 feet. In consists of a tolerably regular cone, somewhat truncated at the top, where it forms three small peaks. The rocks on the beach consist of a conglomerate containing boulders of trachytic porphyry. The island is encircled by dense forest, which it was found impracticable to penetrate in the only recorded visit made by geologists. There can be no reasonable doubt that the island is a volcano; but no eruptions have been recorded, and the igneous action to which the peak is due may be extinct.

GLOSSARY.

ACICULAR: (*acicula*, a little needle). Needle-like, long and fine; a term applied to crystals.

ACROGEN: (ἄκρος, summit; γίγνομαι, I am formed). A subdivision of cryptogamic plants, comprising *Equisetaceæ*, ferns, mosses, &c.

ACTINOLITE: (ἀκτίς, a ray; λίθος, a stone). A variety of hornblende or amphibole, usually of a green colour, and frequently translucent; it occurs in long acicular crystals, and is often found in metamorphic rocks.

ACTINOZOA: (ἀκτίς, a ray; ζῶον, animal). A class of *Cœlenterata*, called also *Anthozoa*.

AGATE: (derivation said to be from the river Achates in Sicily). A variegated form of silica, banded with different colours, or with opaque and translucent layers alternating. It is commonly found lining cavities in basalt and other volcanic rocks.

ALBITE: (*albus*, white). A kind of felspar, usually of a white or grey colour, and differing from orthoclase or common felspar in containing soda instead of potash, and in crystallizing in the triclinic or anorthic system.

ALGÆ: (*alga*, seaweed). A class of cryptogamic plants, comprising various aquatic forms, such as seaweeds, and also very many low types, such as *Confervæ* and *Diatomaceæ*.

ALLUVIUM: (*alluo*, I wash against). Clay, silt, sand, and gravel deposited from water. The term is usually restricted to deposits from rivers, lakes, and seas, still existing, or which existed in very late geological times; and it is especially applied to the deposits formed by rivers when overflowing their banks.

ALUM: (*alumen*). A hydrous double sulphate of alumina and of an alkali. Common alum contains potash.

ALUMINA: An earth: the sesquioxide of the metal aluminium, containing two equivalents of the metal and three of oxygen. Alumina combined with silica is the basis of all clays.

AMETHYST: (ἀμέθυστος). Quartz or rock crystal, of a pink or purple colour, the colour being due to the presence of manganese or iron.

AMMONITE. An extinct genus of tetrabranchiate cephalopod mollusca, chambered within, and coiled in a plane spiral. The shell is distinguished from that of the still-surviving genus *Nautilus* by the sutures being much curved and crenulated, and by the siphuncle being dorsal or external. By many modern palæontologists the genus has been divided into several. Ammonites range from carboniferous to cretaceous, and are especially characteristic of mesozoic strata.

AMORPHOUS: (α, privative, and μορφή, form). A term applied to such mineral substances as present no appearance of crystallization.

AMPHIBIA: (ἀμφί, both, and βίος, life). A class of vertebrate animals, comprising the living frogs, newts, and salamanders, and the extinct *Labyrinthodonta*. By some naturalists these forms are classed with reptiles, but the two differ greatly in embryonic characters, and in the fact that all amphibia breathe with gills during part of their life, whereas reptiles breathe with lungs throughout.

AMPHIBOLE: (ἀμφίβολος, ambiguous; the mineral having been confounded with tourmaline). See "*Hornblende.*"

AMYGDALOID: (ἀμύγδαλον, almond; εἶδος, form). A volcanic rock containing small nodules of quartz, felspar, zeolite, or some other mineral. These minerals have been deposited in cavities which were originally, in most cases, air-bubbles in the molten rock.

ANALCIME: (ἀνάλκις, weak; in allusion to its weak electric power when rubbed). A zeolite, composed chiefly of silica, alumina, and soda, and crystallizing in the cubical or monometric system. The ordinary form is a trapezohedron.

ANAMESITE: (ἀνάμεσος, intermediate). A fine-grained variety of dolerite or basalt, in which the constituent minerals are so minutely crystallized, that the rock appears homogeneous, except under the microscope.

ANASTOMOZE: (ἀναστόμωσις, inosculation). To open into each other. A term applied to the veins of leaves when they unite to form a network.

ANGIOSPERMS: (ἀγγεῖον, a vessel; σπέρμα, seed). The great subdivision of dicotyledonous phanerogamic or flowering plants, with their seeds encased. All ordinary dicotyledonous plants, except cycads, conifers, and *Gnetaceæ* are angiospermous.

ANNELIDA: (*annellus*, a little ring). Annelids, a class of *Annulosa* or *Articulata*, comprising worms, *Serpulæ*, &c.

ANNULOSA: (*annulus*, a ring). A primary division or subkingdom of animals, comprising worms, crustaceans, insects, &c., and corresponding to the Cuvierian *Articulata*.

ANORTHIC: (αν, negative; ὀρθός, straight). A system of crystals distinguished by having the three axes unequal and all obliquely inclined to each other.

ANTHOZOA: (ἄνθος, a flower; ζῶον, an animal). A class of *Cœlenterata*, called also *Actinozoa*, comprising the coral-animals, sea-anemones, and some other forms.

ANTHRACITE: (ἄνθραξ, carbon). Coal, deprived of most of its volatile ingredients, and consisting almost wholly of carbon.

ANTICLINAL: (ἀντί, opposite, and κλίνω, I incline). The curvature of strata in a ridge-like form, the convexity or salient angle being upward.

ANTICLINAL AXIS. A line drawn along the summit ridge of an anticlinal curve.

APATITE: (ἀπατάω, I deceive: the name was given from the resemblance to other minerals). Mineral phosphate of lime, crystallizing in the hexagonal system.

APOPHYLLITE: (ἀποφυλλίζω, I exfoliate). A hydrous silicate of lime and potash, with some fluorine; allied to the zeolites, and occurring in the same manner as zeolites in volcanic rocks. It crystallizes in the tetragonal or pyramidal system.

AQUEOUS ROCKS: (*aqua*, water). Rocks deposited by water, in contradistinction to igneous rocks, the formation of which has been due to heat.

ARENACEOUS: (*arena*, sand). Sandy or composed of sand.

ARGILLACEOUS: (*argilla*, clay). Composed of clay, or containing a large proportion of it.

ARKOSE. A detrital rock, composed of the materials of granite, quartz, felspar, and mica, and consisting frequently of angular fragments of those minerals in a sandy or argillaceous matrix.

ARTHROPODA: (ἄρθρον, a joint; πούς, a foot). Those classes of *Annulosa* which have jointed limbs: spiders, insects, myriapods, and crustaceans.

ARTICULATA: (*articulus*, diminutive of *artus*, a joint). Cuvier's name for the great animal subkingdom comprising worms, insects, crustacea, &c., now classed generally as *Annulosa*, or subdivided into *Annelida* and *Arthropoda*.

ARTIODACTYLA: (ἄρτιος, even; δάκτυλος, a finger or toe). A subdivision of the ungulate or hoofed mammals, having the toes of the feet either two or four in number. This group comprises the ruminants and some of the pachyderms of Cuvier, such as the pig.

ASCIDIOIDA: (ἀσκός, a bag; εἶδος, form). A class of *Molluscoida*, also known as *Tunicata*.

ASH, VOLCANIC. A general name applied to fragments of rock and dust (lapillæ, scoriæ, &c.) ejected from volcanoes. When consolidated, the mass forms a breccia, consisting of larger and smaller masses of various igneous rocks, such as basalt or trachyte, in a finer matrix.

ATOL: (a Malay word). A coral island consisting of a more or less perfect ring of coral rock surrounding a lagoon. The Maldive and Laccadive islands consist of atols.

AUGITE: (αὐγή, lustre). A mineral known also as pyroxene; one of the principal constituents of lavas, and especially of dolerite. It is composed of silica combined with lime, magnesia, iron, and other bases in varying proportions. Augite differs but little in composition from hornblende, and both crystallize in the same system, the oblique or monoclinic, but the angles differ.

AVES: (Latin for birds). Birds: one of the classes of the animal subkingdom of *Vertebrata*.

AZOIC: (α, privative; ζωή, life). A term applied to the oldest rocks, in which no organic remains have hitherto been discovered. See p. 37.

BACKWATER. A name applied to expanses of salt water close to the coast, and separated from the sea by sand-spits.

BASALT: (*basaltes*, Gr. and Lat.) An igneous rock, composed of augite and labradorite, often with olivine in disseminated grains. The term is chiefly applied to the hard, black, crystalline form of dolerite, and especially to that variety of the rock which exhibits prismatic structure.

BASIN. A defined area composed of strata, dipping in a concave form from the circumference towards the interior.

BASSET or BASSET EDGE. A miner's term for the outcrop of a bed.

BATHYMETRICAL: (βάθος, depth; μέτρον, measure). Distribution according to depth in the sea.

BATRACHIA: (βάτραχος, a frog). The *Anura* or tail-less *Amphibia*, including frogs and toads.

BED. A single definite layer of a sedimentary rock, irrespective of thickness.

BELEMNITE: (βέλεμνον, a dart). An extinct genus of dibranchiate *Cephalopoda*, having a straight, subcylindrical internal shell of great strength, solid and pointed at one end, and expanded so as to form a conical chambered area, known as the phragmocone, at the other. Belemnites abound in mesozoic rocks, especially in middle secondary or jurassic strata.

BERYL: (βήρυλλος). A mineral composed of silicate of alumina and glucina, crystallizing in the hexagonal system, and usually occurring in hexagonal pyramids. Emerald is a finely coloured and transparent variety of this mineral.

BHÁBER: (Hindi). See p. 403.

BHÁNGAR: (Hindi). See p. 404.

BHIL: (Bengali) = jhil: a marsh. See p. 406.

BIOTITE: (named after M. Biot). Uniaxial or magnesian mica; a silicate of alumina, iron, and magnesia, crystallizing in the hexagonal system, and usually dark-green or black in colour.

BOTRYOIDAL: (βότρυς, a bunch of grapes; εἶδος, form). Minerals and rocks are thus termed when, owing to concretionary structure, the surface is raised into numerous convex projections, resembling grapes.

BOULDER. A mass of transported rock, too large to be classed as a pebble.

BRACHIOPODA: (βραχίων, the arm; πούς, foot). A class of bivalve shells, placed by some naturalists with true mollusca, but by most modern systematists in the *Molluscoida*, with *Bryozoa* and *Tunicata* or *Ascidioida*. The *Brachiopoda* may be distinguished from true bivalve mollusca or *Lamellibranchiata* by their bilateral symmetry, by the structure of the hinge and texture of the shell, and, in many cases, by having one valve larger than the other.

BRECCIA: (Italian). A rock composed of angular fragments cemented together.

BRONZITE. A mineral allied to pyroxene, consisting of silicate of magnesia, with a variable proportion of iron, having frequently a bronze colour and lustre, and often associated with serpentine. Called also *Enstatite*.

BROWN-COAL. Lignite of a brown colour, found in tertiary rocks, and so abundant in certain miocene beds in Germany, as to have been furnished a name used by many geologists for a particular epoch.

BRYOZOA: (βρύον, moss; ζῶον, an animal). A class of compound aquatic animals, called also *Polyzoa*, forming a coating of cells on sea-weed, shells, rocks, &c., or else branched aggregates (corallines). One of the best known forms is the sea-mat or *Flustra*. The *Bryozoa* were formerly classed with the *Radiata*, and subsequently with *Mollusca*; but by most modern systematists they are placed in the *Molluscoida* with *Brachiopoda*, to which they are nearly allied in structure.

BUNTER: (German; variegated). The name applied to a subdivision of the Trias formation in Germany, on account of the prevalence of variegated sandstones. The term is now used for a group of the new red sandstone, in England and elsewhere, equivalent to the German Bunter.

CÆNOZOIC or CENOZOIC: (καινός, recent; ζωή, life). The latest great sub-division of geological time. The name has been applied by some geologists, in preference to tertiary, in order to preserve uniformity of nomenclature, and to introduce a term corresponding to mesozoic and palæozoic.

CALCAIRE GROSSIER: (Fr., coarse limestone). The name of an important subdivision of the French eocene tertiary beds.

CALCAREOUS: (*calx*, lime). Composed of lime, or containing a considerable quantity of it.

CALCITE: (*calx*, lime). Mineral carbonate of lime, crystallizing in the hexagonal system.

CAMBRIAN. A subdivision of palæozoic rocks, inferior to the silurian. The name is derived from Cambria or Wales.

CARBONIFEROUS: (*carbo*, coal; *fero*, I bear). A subdivision of upper palæozoic rocks, resting upon the devonian, and beneath the permian. The name is derived from the circumstance that all the most important coal beds of Western Europe belong to the formation.

CARNIVORA: (*caro*, flesh; *voro*, I devour). An order of mammalia, comprising cats, dogs, weasels, civets, bears, seals, &c.

CATACLYSM: (*κατακλυσμός*, inundation). A violent flood or deluge.

CENOMANIAN: (from *Cenomanum*, the Latin name for the town of Mans). A group of the cretaceous system, nearly corresponding to the upper greensand of English geologists.

CEPHALOPODA: (*κεφαλή*, head; *πούς*, foot). A class of mollusks, comprising cuttle fish, argonauts, *Nautili*, *Ammonites*, *Belemnites*, &c.

CETACEA: (*κῆτος*, a whale). An order of mammalia comprising whales and porpoises.

CERATITES: (*κέρας*, a horn). A genus of *Cephalopoda*, nearly allied to *Ammonites*, but distinguished by a more simple form of suture. The distinction, however, is now known to be less important than was formerly supposed. The genus is almost peculiar to triassic strata, though species have been found in carboniferous beds in India.

CERUSITE: (*cerussa*, white lead). Mineral carbonate of lead.

CHABASITE: (*χαβάζιος*, a kind of stone). A zeolitic mineral, a hydrated silicate of alumina, lime and soda with a little potash, crystallizing in the rhombohedral system, and generally occurring in basalt.

CHALCEDONY or CALCEDONY: (derived from the town of Chalcedon). A variety of uncrystallized silica, with a waxy lustre, and either transparent or translucent.

CHALCOPYRITE: (*χαλκός*, brass; *πυρίτης*, pyrites). Copper pyrites, sulphide of copper and iron, crystallizing in the pyramidal system.

CHALK. A soft white limestone. A rock of this kind, belonging to the upper cretaceous period, is largely developed in England and France, and has furnished the name used for the period.

CHAR: (Hindi; frequently written *chur*). A sandbank in a river. The term is applied to the banks of sand and silt left dry on the subsidence of rivers after the flood season, and frequently cultivated during the dry weather.

CHERT. Impure silica, or flinty portions of rocks.

CHIROPTERA: (*χείρ*, hand; *πτερόν*, wing). An order of mammalia comprising the bats.

CHLORITE: (*χλωρός*, green). A hydrated silicate of alumina, iron and magnesia, resembling mica, but of a green colour and very soft, occurring chiefly in scales and small crystals in metamorphic rocks.

CHONDRODITE : (χόνδρος, grain). A silicate of magnesia, with part of the oxygen replaced by fluorine, occurring usually as yellow or brown grains in crystalline limestone.

CHRYSOLITE : (χρυσός, gold). A mineral identical with olivine, composed of silicate of magnesia and iron, and crystallizing in the prismatic or orthorhombic system.

CHRYSOTILE : (χρυσός, gold; τίλος, hair). A fibrous variety of serpentine with a silky lustre, and frequently a yellow or green colour.

CILIOPODA : (*cilium*, an eyelash; πούς, a foot). A name proposed by Dr. Stoliczka for *Bryozoa*.

CLASS. In zoology, one of the great subdivisions of the animal kingdom, below the rank of subkingdoms. Rhizopods, sponges, corals, echinoderms, crustacea, insects, brachiopods, cephalopods, fishes and mammals are classes.

CLASTIC : (κλαστός, broken in pieces). Detrital: a general term applied to rocks formed from broken fragments of other rocks. The term is intended to include breccias, volcanic ash, and re-arranged detritus of all kinds, as well as ordinary sandstones, conglomerates, clays, &c.

CLAY IRONSTONE. A mixture of carbonate of iron and clay, found in beds and nodules, and especially common in the coal-measures.

CLAYSTONE. A term of somewhat loose application, generally used for compact felspar, felsite, or very felspathic igneous rocks. The term is also applied to disintegrated felsite, and sometimes, but rarely, to a sedimentary rock composed of hardened clay.

CLEAVAGE. A fissile structure, not due to the original bedding of a rock, nor, as a rule, coincident with it. Cleavage is characteristic of true slates, and has been shewn to be due to pressure exercised at right angles to the cleavage planes.

COAL. Vegetable tissue, converted into a substance proportionally poorer in water and volatile ingredients, and richer in carbon. Lignite has undergone less change than coal, but the two pass into each other.

CŒLENTERATA : (κοῖλος, hollow; ἔντερα, viscera). A group of animals distinguished from the lower forms (*Infusoria* and *Protozoa*) by having a hollow digestive cavity. This group comprises the *Anthozoa* or *Actinozoa* and *Hydrozoa*, and, according to some naturalists, the Sponges.

COLOSSOCHELYS : (κολοσσός, gigantic statue; χελύς, tortoise). A gigantic genus of tortoise, found in Siwalik rocks.

COMPACT. Firm and close-grained: a term applied to rocks.

CONCHIFERA : (*concha*, a shell; *fero*, I bear). A name formerly used by some naturalists for *Lamellibranchiata*.

CONFORMABLE. Beds having their stratification planes perfectly parallel, and in which the lower has not been eroded before the deposition of the upper.

CONGLOMERATE: (*con*, together, and *glomero*, I collect). Rocks composed of rounded pebbles cemented together, or imbedded in a sandy argillaceous or calcareous matrix.

CONIFERÆ: (*conus*, a cone; *fero*, I bear). An order of gymnospermous exogens, including pine and fir trees and their allies, and largely developed in past epochs.

COPPER GLANCE. Native sulphide of copper, crystallizing in the prismatic or orthorhombic system, and known also as chalcocite, redruthite, and vitreous copper.

COPPER PYRITES. Sulphide of copper and iron, containing, when pure, 34·6 per cent. of copper, crystallizing in the pyramidal or tetragonal system.

COPROLITE: (κόπρος, dung). Petrified excrement.

CORAL: (κοράλλιον). A general term for the calcareous structures secreted by *Anthozoa* and *Hydrozoa*.

CORAL REEF. A shoal or low island formed by the growth of corals, and by the accumulation and consolidation of their debris. In many tropical seas, archipelagoes of great extent are entirely formed of coral reefs. These have been shewn to have been built upon submerged land, the reef-building coral animals, which can only live at certain moderate depths, having gradually built up the island as the base sank.

CORUNDUM: (*kárand*, Hindi). Pure alumina, crystallizing in the hexagonal system. Sapphire and ruby are forms of corundum, and emery is a granular variety, mixed with magnetite or hæmatite.

COSMOGONY: (κόσμος, world; γονή, origin). An hypothesis of the origin of the universe.

CRAG. The local name for the pliocene beds of Eastern England.

CRATER: (κρατήρ, a cup). The orifice of a volcano.

CRINOIDEA: (κρίνον, a lily; εἶδος, form). An order of *Echinodermata* consisting of a cup-like body, giving off a variable number of arms (usually five), and either supported on a jointed peduncle or sessile.

CROP: CROP OUT. To appear at the surface. See "*Outcrop*."

CRUSTACEA: (*crusta*, a shell). A class of arthropodous *Annulosa*, or articulated animals, including crabs, lobsters, cyprides, cirripeds, *Squillæ*, wood-lice, king-crabs, copepods, trilobites, &c.

CRYPTOGAMIA: (κρυπτός, concealed; γαμέω, I marry). One of the primary divisions of plants, in which flowers and cotyledonous seeds are wanting.

CRYSTAL: (κρύσταλλος, ice). A mineral or salt having regular polyhedral structure. All crystalline forms known are divided into six systems: the cubical or isometric; the pyramidal, dimetric, or tetragonal; the prismatic, trimetric, or orthorhombic; the hexagonal or rhombohedral; the monoclinic or oblique; and the triclinic or anorthic.

CTENOID: (κτείς, a comb; εἶδος, form). An order of fishes in Agassiz' arrangement, distinguished by their scales being pectinated on the posterior margin.

CUBICAL. A system in crystallography in which all the three axes are equal and at right angles to each other.

CYCADEACEÆ. A great subdivision or natural order of gymnospermous exogens, comprising a few living genera, as *Cycas* and *Zamia*, and numerous extinct forms.

CYCLOID: (κύκλος, a ring; εἶδος, form). An order of fishes in Agassiz' arrangement, distinguished by having round smooth scales, with a simple margin.

CYCLOPTERIS: (κύκλος, a ring; πτερίς, a fern). A genus of fossil ferns, distinguished by having more or less rounded leaflets, without a midrib, but with dichotomous veins, radiating from the base to the margin.

CYPRIS. A genus of bivalve entomostracous freshwater crustaceans, having two flattish valves, with elliptical outlines.

DEBRIS: (*dêbris*, fragments or wreck). An accumulation of loose material derived from the waste of rocks.

DEGRADATION. The wasting and wearing away of rocks by atmospheric or aqueous action.

DEINOSAURIA. See "*Dinosauria.*"

DEINOTHERIUM. See "*Dinotherium.*"

DELTA. The alluvial land near the mouth of a river. The name was originally given to the triangular tract near the mouth of the Nile, and was derived from the resemblance of this area in form to the Greek letter Δ.

DENUDATION: (*denudo*, I lay bare). The removal of the superficial crust of the earth by the agency of the atmosphere and water.

DEPOSIT: (*depono*, I lay down). Any substance originally suspended or dissolved in water and precipitated therefrom.

DETRITUS: (*detero*, I rub off). Material removed by disintegration and other agencies from the surface of rocks.

DEVONIAN. A subdivision of palæozoic formations, resting upon the silurian, and overlain by carboniferous. The name is derived from the county of Devon in England.

DIABASE: (διάβασις, a passage). A compound of plagioclase felspar (oligoclase, labradorite, albite or anorthite), with pyroxene and some chlorite. The rock in its fresh state is dark-green; it is usually fine-grained or micro-crystalline, and is distinguished from dolerite by the presence of chlorite.

DIALLAGE: (διαλλαγή, difference). A foliated form of pyroxene, usually of a green or greenish grey colour. The name is also applied to forms of the allied minerals, bronzite and hypersthene.

DIASPORE : (διασπείρω, I scatter). A hydrate of alumina, crystallizing in the prismatic system, and found in small scattered crystals associated with corundum.

DICOTYLEDONOUS : (δίs, twice; κοτυληδών, seed lobe). Exogenous: the great subdivision of phanerogamous or flowering plants, distinguished by having seeds with two or more lobes or cotyledons, leaves with divided veins, and wood, if any, arranged in concentric layers.

DICYNODON : (δίς, twice ; κύων, a dog; ὀδούς, tooth). An extinct reptile with two canine-like teeth, found hitherto in South Africa and India only.

DIKE. See "*Dyke.*"

DILUVIUM : (Lat., a deluge). This term is used, as opposed to alluvium, to indicate deposits produced by extraordinary water action. It was thus applied to the drift gravels, boulder clays, and erratics attributed originally to a deluge; and although the name is now but little used by English geologists, it is still commonly applied by French and German writers in the sense of post-tertiary or pleistocene.

DIMETRIC : (δίς, twice; μέτρον, a measure). A name formerly used by Dana for the pyramidal system in crystallography, now called by him tetragonal.

DINOSAURIA : (δεινός, terrible; σαύρα, lizard). An extinct order of reptiles having marked affinities with birds. The order included, amongst other genera, *Ignanodon* and *Megalosaurus.*

DINOTHERIUM : (δεῖνος, terrible ; θηρίον, a beast). A genus of proboscidian mammals, having a very different dentition from *Elephas* and *Mastodon.*

DIORITE : (διοράω, I distinguish). A rock, usually fine-grained, of a dark-green colour, and consisting of felspar (not orthoclase) and hornblende.

DIP. The angle at which a stratum slopes from the horizontal plane of the earth's surface.

DIPTERA : (δίs, twice ; πτερόν, a wing). An order of insects, including flies and gnats, and distinguished by having only two wings.

DOAB : (*do*, two ; *áb*, water : Persian). The area between two confluent rivers, and the confluence itself.

DOLERITE : (δόλος, a trick or deceit). A rock of volcanic origin, composed of labradorite and pyroxene, and distinguished from trachyte and its allies by the much larger proportion of bases to silica.

DOLOMITE : (named after Dolomieu). Magnesian limestone : a carbonate of lime and magnesia in equal proportions when pure.

DUNE : (Fr.) A sand-hill.

DYKE. Volcanic or plutonic rock, filling a crack in a pre-existing formation.

Echinodermata: (ἐχῖνος, a hedgehog; δέρμα, skin). A great class of invertebrate animals, including sea urchins, star-fishes, brittle-stars, feather-stars, sea-slugs (*Holothuridea*), &c.

Edentata: (*e*, without; *dens*, a tooth). An order of mammalia in which the teeth are absent or deficient. The sloths, pangolins, anteaters, and armadillos belong to this order.

Efflorescence: (*effloresco*, I put forth flowers). A saline crust forming on the surface of the ground or on rocks.

Elvan. A Cornish term for a felsitic rock, occurring in dykes. For *Elvanite*, see "*Porphyry*."

Elytrum: (ἔλυτρον, a cover). The wing case of a beetle, being one of the anterior pair of wings which are modified into sheaths to cover the second pair.

Enaliosauria: (ἐνάλιος, marine; σαύρα, lizard). An extinct order of reptilia, fitted to live in the sea, and comprising *Ichthyosaurus*, *Plesiosaurus*, &c. It is now considered to include two distinct orders, the *Ichthyosauria* and *Plesiosauria*.

Encrinites. A genus of fossil crinoids. The term is often used for fossil crinoids generally.

Endogen: (ἔνδον, within; γίγνομαι, I am formed). Monocotyledonous flowering plants, such as grasses, palms, lilies, &c., with simple veined leaves, seeds with one cotyledon, and the wood, if any, not in concentric layers.

Entomostraca: (ἐντέμνω, I cut up; ὄστρακον, a shell). The lower crustacea, so called from the segments of their bodies being unconsolidated.

Eocene: (ἠώς, dawn; καινός, recent). The lowest great subdivision of tertiary strata.

Eolian: (*Eolus*, god of the winds). A term occasionally applied to wind-carried formations, such as blown sand.

Epidote: (ἐπίδοσις, increase). A mineral composed of silicate of alumina, iron and lime, crystallizing in the oblique system, and generally of a green colour.

Epistilbite: (ἐπί, upon; and στίλβη, lustre). A zeolite; a hydrated silicate of alumina and lime, with some soda, crystallizing in the oblique system.

Epoch. A period in geological time.

Erratic. A transported fragment of rock, at a distance from the original bed. The term has been especially applied to the blocks of stone scattered over the plains of Europe, and formerly supposed to have been transported by a deluge, or wave of translation, but now generally considered to have been carried by ice; hence the term "erratic" has become generally synonymous with an ice-borne boulder.

Escarpment. An inland cliff, usually produced by the outcrop of a hard stratum.

ESTHERIA. A genus of bivalve crustacea.

EUPHYLLITE: (εὖ, beautiful; φύλλον, a leaf). A mica-like mineral belonging to the margarophyllite section, and composed of hydrated silicates of alumina, lime, potash, and soda.

EXOGEN: (ἔξω, outside; γίγνομαι, I am formed). The same as "*dicotyledonous*."

EXUVIÆ: (Lat., cast clothes). Remains of animals, especially the shelly coverings of invertebrates.

FACIES: (Lat., the face). A term used to imply the general aspect or relations of a fauna or flora.

FALSE BEDDING. Oblique lamination; the arrangement of sand and other materials of which a bed is composed in laminæ not parallel with the planes of bedding. False bedding is especially common in beds of sandstone deposited by running water, as by a river, or by tidal currents in the sea.

FAMILY. In zoology and botany, a group of allied genera.

FAULT. A miner's term for any break in the continuity of a coal seam or mineral vein, however caused. In geology, the name is only applied where fracture of any rocks has taken place, accompanied by the shifting, either vertical or horizontal, of the opposite faces of the crack.

FAUNA (*Fauni*, rural deities). The whole collection of animals inhabiting a given area, or preserved in a particular bed or formation.

FELSPAR or FELDSPAR: (the latter spelling is correct, the word being derived from the German *feldspath*). A very important group of minerals, one or the other species being a principal constituent of almost all igneous rocks. Orthoclase, albite, oligoclase, and labradorite are felspars; all consist of double silicates of alumina and one or more alkalies or alkaline earths, and crystallize in the oblique or anorthic system.

FELSITE or FELSTONE. A rock of compact texture, usually pale coloured, but sometimes black or brown, weathering white, composed chiefly of felspar with some quartz. Felsite is the matrix of most porphyries.

FENESTELLA: (Lat., a little window). A genus of *Bryozoa* found in the palæozoic rocks.

FERRUGINOUS: (*ferrugo*, iron rust). Impregnated with iron oxide.

FIRECLAY. Clay capable of resisting great heat without fusing.

FLAG OR FLAGSTONE. Hard laminated or fissile stone, especially hard sandstone in thin slabs.

FLINT. Silicious concretions, usually translucent and tolerably homogeneous, occurring in chalk or limestone.

FLORA: (the goddess of flowers). The whole collection of plants inhabiting a given area, or preserved in a particular bed, formation, group, or series.

FOLIATION. The arrangement in alternating laminæ of different minerals, as commonly occurs in gneiss and other metamorphic rocks.

FORAMINIFERA : (*foramen*, a small opening; *fero*, I bear). A group of *Rhizopoda*, living in hollow perforated shells, frequently chambered. *Globigerina*, *Alveolites*, and *Nummulites* are examples.

FORMATION. An assemblage of rocks of similar origin, connected by mineral characters, by organic remains, or by being of the same geological age.

FOSSIL : (*fossilis*, dug out of the earth). Originally, this term applied to all mineral substances; now, it is restricted to organic remains, animal or vegetable, imbedded in rocks.

FREESTONE. A stone, usually a sandstone, easily cut and dressed.

FUCOID : (*fucus*, sea-weed). A sea-weed, or a similar plant.

GABBRO : (Ital.) A rock composed of labradorite and diallage or hypersthene (bronzite). It is frequently associated with serpentine.

GALENA : (Lat.) Native sulphide of lead, crystallizing in the cubical system.

GANOID : (γάνος, brightness; εἶδος, form). An order of fishes, distinguished for the most part by hard polished rhomboidal scales. Ganoids are far more common in the upper palæozoic and lower mesozoic formations than at present.

GARNET : (*granatus*, like a grain). A mineral, crystallizing in the isometric or cubical system, and composed of silicate of alumina and lime or iron; the alumina often replaced by sesquioxide of iron, and the lime by magnesia or some other oxide.

GASTEROPODA : (γαστήρ, belly; πούς, foot). A class of mollusks, comprising ordinary univalves, whelks, cowries, cones, periwinkles, limpets, &c.

GAULT. An argillaceous bed in the cretaceous formation between the upper and lower greensand.

GENUS : (Lat., a race). A group of allied species.

GHÂT : (Hindi). A landing-place, ford, or pass. This term "ghâts," originally applied to the passes through the mountain ranges that run parallel, or nearly so, to the coasts of the peninsula, has now been transferred to the ranges themselves.

GLACIAL EPOCH. A period of low temperature intervening between tertiary and recent times.

GLACIER (French). A mass of ice moving slowly down the valleys and other depressions of snow-clad mountains, and formed by the accumulation and consolidation of snow.

GLAUBERITE. Native anhydrous sulphate of lime and soda, crystallizing in the oblique system.

GLOSSOPTERIS : (γλῶσσα, the tongue; πτερίς, a fern). A genus of simple leaved ferns, with reticulate venation and a distinct midrib, com-

mon in the Indian coal-bearing rocks of the Damúda period, and in Australian coal-measures, but rare elsewhere.

GNEISS: (a German miner's term). A highly foliated rock, composed of quartz, felspar, and mica in crystals. The mica is sometimes replaced by hornblende, and garnets or other minerals are imbedded. Gneiss passes by insensible gradations into granite.

GONIATITE: (γωνία, an angle). A genus of *Cephalopoda* allied to *Ammonites*, but distinguished by having the sutures in angulate zigzag lines.

GRANITE. A plutonic rock, rich in silica, and composed of felspar, quartz, and mica. The felspar is almost always orthoclase; a second felspar, usually oligoclase, being frequently present also. In some forms of granite the mica is absent (aplite or pegmatite).

GRAPHITE: (γράφω, I write). A form of carbon, occurring pure or mixed with more or less iron oxide in crystalline rocks.

GRAPTOLITES: (γράφω, I write; λίθος, a stone). A group of fossils, characteristic of the cambrian and silurian periods, composed of straight or curved rods, with denticulation corresponding to cells on one or both sides, and supposed to have been *Hydrozoa*, allied to the recent sertularian zoophytes.

GRAUWACKÉ. A German miner's term for the older argillo-arenaceous beds, and often employed at one time as a name for the transition series. The term is now obsolete.

GRAVEL. Loose pebbles, with or without sand.

GREEN-EARTH. A hydrous silicate of iron and potash, found chiefly in basalt and other eruptive rocks.

GREENSAND. The name of two important subdivisions of the cretaceous system in England—the upper and lower greensands.

GREENSTONE. A general name for igneous rocks, composed principally of felspar and hornblende. By some writers certain plutonic rocks containing augite are also called greenstones.

GREYWACKÉ. See "*Grauwacké*."

GRIT. A coarse sandstone, or, according to some writers, a sandstone in which the grains of quartz are angular. The term is applied somewhat loosely.

GROUP. An association of beds agreeing in mineral character, or varying amongst themselves in mineral character, but containing the same fossils. The terms "group" and "series" are frequently used by geologists as equivalent terms. In the present work, "series" is always understood as implying a more extended range of formations, and usually as comprising several "groups."

GYMNOSPERMS: (γυμνός, naked; σπέρμα, seed). Dicotyledonous flowering plants, with naked seeds composed of two or more cotyledons. Conifers and cycads are included.

GYPSUM: (γύψος, lime or chalk). Hydrated sulphate of lime, crystallizing in the oblique system.

GYROGONITES: (γυρός, round; γόνος, seed). The spiral seed vessels of *Characeæ*, found in freshwater beds.

HABITAT. The country, district, or kind of locality in which an animal or plant is found living in a wild state.

HÆMATITE: (αἷμα, blood). Native iron oxide in a massive form, either crystalline or amorphous. The crystalline variety, known as specular iron, crystallizes in the hexagonal system.

HEMIHEDRAL: (ἡμι, half; ἕδρα, side). Crystalline forms made from other regular solids by the obliteration of half of the bounding planes.

HEULANDITE: (named after Heuland, a mineralogist). A zeolitic mineral; a hydrous silicate of alumina and lime, crystallizing in the oblique or monoclinic system.

HEXAGONAL: (ἕξ, six; γωνία, angle). A system in crystallography in which four axes are present, three equal lateral axes meeting at angles of 60°, and the vertical axis at right angles to the others.

HIPPARION (ἱππάριων, diminutive of ἵππος, horse,) or HIPPOTHERIUM. A genus of mammals found in the later tertiaries, and closely allied to the horse, but distinguished by the lateral digits of the feet being better developed and furnished with hoofs.

HIPPURITES: (ἵππουρις, a horse-tail). A genus of cretaceous bivalves of very peculiar form, one valve being conical or shaped like a horn, the other resembling a lid.

HORNBLENDE. A silicate of various bases, usually lime, magnesia, or iron, or combinations of these with each other, part of the silica being often replaced by alumina. The crystallization is oblique. Hornblende is an important constituent of many igneous rocks, such as syenite, diorite, &c.

HORNSTONE. A variety of flint or chert, resembling horn in appearance.

HYDROZOA: (ὕδρα, a water dragon; ζῶον, an animal). A class of animals belonging to the subkingdom *Cœlenterata*, allied to the *Anthozoa*, and comprising the hydroid or sertularian polypes, most of the jelly-fishes (*Acalephæ*), and some other forms.

HYPERSTHENE: (ὑπέρ, very; σθένος, tough). A silicate of iron and magnesia, usually containing also some lime and alumina, closely allied to bronzite.

HYPOGENE: (ὑπό, below; γίγνομαι, I am made). A term proposed by Lyell for the metamorphosed sedimentary formations formerly known as primary. The term is intended to express the idea that the beds in question had been transformed from below.

ICHTHYOSAURUS: (ἰχθύς, fish; σαύρα, lizard). An extinct genus of reptiles inhabiting the sea, having no exo-skeleton, the limbs converted into paddles, a large head, short neck, and probably a tail like that

of *Cetacea.* The genus gives its name to the order *Ichthyosauria,* which abounded in the mesozoic epoch, and especially in jurassic times.

IGNEOUS: (*ignis,* fire). A term applied to all geological phenomena supposed to be due to the action of heat. Igneous rocks are such as are believed to have undergone fusion. Particular igneous rocks were formerly supposed to be characteristic of different geological epochs, and some geologists still believe in the distinction, which has, however, been entirely abandoned by all the best English writers.

ILMENITE: (named after Ilmen). Titaniferous iron ore; hæmatite, in which part of the iron is replaced by titanium.

INFRA: (Lat., below). Applied to strata, *infra* implies a lower position: thus Infra-Król (p. 600) is the name of a group inferior to the Król; Infra-Vindhyan implies beds underlying the Vindhyans.

INFUSORIA: (*in,* and *fundo,* I pour). A class of microscopic animals, named from their occurrence in vegetable infusions.

INNATE: (*in,* and *natus,* born). A term applied to certain igneous rocks, which have undergone transformation, without intrusion or other change of position. Such rocks are believed to have been found by simple fusion *in situ.*

INSECTA: (*inseco,* I cut in pieces). A class of the arthropodous subdivision of *Annulosa,* characterized in all perfect forms by the possession of three pairs of legs attached to the thorax, and in most cases by two pairs of wings.

INSECTIVORA: (*insectum,* an insect; *voro,* I devour). An order of mammalia, comprising moles, shrews, hedghogs, *Tupaiæ,* &c.

IN SITU: (Lat., in place). A term applied to a rock or fossil when still in the exact position in relation to the matrix or surrounding rocks in which it was formed or deposited.

INVERTEBRATA: (*in,* privative; *vertebra,* a joint). All animals except the *Vertebrata.*

IRONSTONE. Any ore of iron; but generally the name is employed for carbonates, especially the argillaceous carbonate of iron so common in the coal-measures, and generally known as "clay ironstone."

ISOMETRIC: (ἴσος, equal; μέτρον, a measure). Dana's name for the cubical system in crystallography.

ISOTHERMAL: (ἴσος, equal; θέρμη, heat). Equal in temperature: a name applied to lines and zones of equal temperature, for any given period, on the earth's surface.

JADE. A name applied to several hard compact minerals, resembling each other in being tough, translucent, and very homogeneous in texture. One form (nephrite) is a variety of amphibole, another (jadeite) is a silicate of alumina and soda.

JASPER. Impure opaque coloured quartz, often of a bright red colour, or striped red and black or white.

JET: (*gagates*, from Gagas, a place in Lycia). A variety of coal having a very low specific gravity, homogeneous texture, and resinous lustre.

JHÍL: (Hindi). A marsh or shallow lake.

JOINTS. Parallel fissures or planes dividing rocks into more or less regular masses.

JURASSIC: (from the Jura mountains.) A system of rocks belonging to the mesozoic period, comprising the lias and oolite, and intervening between the trias below and the cretaceous above. By some geologists, the lias is separated from the jurassic system, and the latter then corresponds with the oolitic series of English geologists.

KANKAR. See p. 381.

KAOLIN: (Chinese). Fine porcelain clay, derived from the decomposition of felspar.

KEUPER: (German). The upper subdivision of the triassic system.

KHÁDAR. See p. 403.

KHÁL: (Bengali). A tidal creek.

KIESERITE: (from Kieser, a proper name). Hydrous sulphate of magnesia, crystallizing in the prismatic system.

KNORRIA: (from Knorr, a proper name). A carboniferous genus of *Lycopodiaceæ*, founded on stems with projecting leaf-scars arranged in a spiral.

KUNKUR. See p. 381.

KUPFERSCHIEFER: (*kupfer*, copper; *schiefer*, slate). A subdivision of the permian system in Germany.

LABRADORITE: (from Labrador, the original locality). A kind of felspar composed of silica, alumina, lime, and soda, crystallizing in the anorthic or triclinic system, and forming a constituent of many igneous rocks, such as basalt and diabase. Labradorite, when in large crystals, is often distinguished by a peculiar play of colours on the surface.

LABYRINTHODON: (λαβύρινθος, a labyrinth; ὀδούς, a tooth). An extinct genus of *Amphibia*, named from the complicated foldings on the transverse sections of the teeth. From this genus the order *Labyrinthodonta* was named: it comprised salamandriform animals with a long tail, and existed in upper palæozoic and lower mesozoic times.

LACUSTRINE: (*lacus*, a lake). Of or belonging to a lake.

LAGOON: (*laguna*, Ital.) A shallow salt-water lake or inlet, nearly or entirely cut off from the sea.

LAMELLIBRANCHIATA: (*lamella*, a thin plate; βράγχια, gills). A class of *Mollusca*, comprising ordinary bivalve shells, such as oysters, mussels, cockles, &c.

LAMINATION: (*lamina*, a thin plate). The division of rocks into thin parallel layers.

LAPILLI: (*lapillus*, a little stone). The finer forms of volcanic ash.

LATERITE. See p. 349.

LAUMONITE or LAUMONTITE: (from Laumont, the name of the discoverer). A hydrous silicate of alumina and lime, crystallizing in the oblique system, and usually found in the cavities of basalt and similar rocks associated with zeolites.

LAURENTIAN. Some of the oldest rocks in Canada, of age anterior to the Cambrian, and named thus from the river St. Lawrence. From these rocks the fossil *Eozoon*, supposed to be the oldest form of life known, was first obtained. The nature of this fossil is, however, disputed, and by some naturalists its organic origin is doubted.

LAVA: (Ital.) The molten rock that flows from a volcano in eruption. Lavas have the same composition as intrusive volcanic rocks, and are divided into two great sections: (1) Doleritic or basic, consisting largely of pyroxene, and not containing more than 45 to 55 per cent. of silica; and (2) trachytic or acidic rocks, with 60 to 80 per cent. of silica, and composed mainly of felspar.

LEPIDOLITE: (λεπίς, scale). A kind of mica containing lithia.

LEUCITE: (λευκός, white). A silicate of alumina and potash, crystallizing in the cubical or isometric system, and found in volcanic rocks.

LEUCOPYRITE: (λευκός, white; πυρίτης, pyrites). Arsenide of iron, crystallizing in the prismatic system.

LIAS. The rocks at the base of the jurassic or oolitic system, classed by some with that system, by others as a distinct formation, intermediate between the oolites and the trias.

LIGNITE: (*lignum*, wood). Fossil wood, carbonised and altered, but still containing a much larger proportion of volatile ingredients than true coal.

LIMESTONE. Indurated carbonate of lime.

LITTORAL: (*littus*, the shore). A term applied to deposits formed in shallow water close to the coast.

LOAM. A soil composed of clay and fine sand.

LOESS. A term applied to a very fine unstratified or imperfectly stratified formation, composed of clay, very fine sand, and some carbonate of lime, occurring in the Rhine valley. Similar beds of great thickness have been found in China and other parts of Central Asia, and shewn to have been probably formed of fine dust transported by the wind.

LYCOPODIACEÆ. A class of acrogenous cryptogamic plants comprising the living club-mosses and numerous fossil forms.

LYDIAN STONE. A black siliceous rock, either a kind of jasper, or an altered siliceous shale.

MAGNETITE: MAGNETIC IRON ORE. An ore of iron composed of one equivalent of sesquioxide and one of protoxide, or of three equivalents of iron and four of oxygen. It crystallizes in the isometric or cubical system, and is usually found in octohedra.

MAMMALIA: (*mamma*, breast). The highest class of *Vertebrata*, comprising all animals that suckle their young.

MARBLE. Properly this term is only applied to the finer and more crystalline forms of limestone. Commonly, however, all rocks capable of being polished are thus called.

MARL. Clay mixed with carbonate of lime, but not consolidated into hard rock. The term is sometimes erroneously applied to non-calcareous clays.

MASTODON: (μαστός, breast; ὀδούς, tooth). An extinct genus of *Proboscidea*, closely allied to the elephant, but distinguished by the form of the teeth, which bear a number of rounded protuberances on the surface.

MEGALOSAURUS: (μεγάλο-great; σαῦρος, lizard). A genus of *Dinosauria*, of great size, with curved sabre-shaped teeth.

MESOZOIC: (μέσος, middle; ζωή, life). All formations, from the trias to the cretaceous inclusive, belonging to the middle or intermediate period between the palæozoic and tertiary or cænozoic epochs.

METAMORPHIC ROCKS: (μετά, after; μορφή, form). Rocks which have undergone a change of structure and become crystalline. The term is especially applied to sedimentary formations, which, through the agency of heat or chemical action, have acquired crystalline structure.

MICA: (*mico*, I shine). A group of minerals, distinguished by being easily split into thin elastic plates, composed of silicates of alumina and various earths and alkalies, and largely developed in crystalline rocks.

MICA SCHIST. A metamorphic foliated rock composed of mica and quartz.

MICACEOUS IRON ORE. A variety of hæmatite occurring in scales like mica.

MIOCENE: (μείων, less; καινός, recent). The middle subdivision of tertiary formations, above the eocene, and below the pliocene.

MOLLUSCA: (*mollis*, soft). One of the primary divisions or subkingdoms of animals, comprising cuttle-fish and ordinary univalve and bivalve shells, or *Cephalopoda*, *Gasteropoda*, *Pteropoda*, and *Lamellibranchiata*.

MOLLUSCOIDA: (*mollusca*, and εἶδος, resemblance). A primary division or subkingdom made for certain classes formerly united with *Mollusca*, but considered distinct by many modern naturalists. These classes are *Ascidioida* or *Tunicata*, *Bryozoa* or *Polyzoa*, and *Brachiopoda*.

MONOCLINAL: (μόνος, single; κλίνω, I incline): A bend, curve, or angle in strata, where one portion of the stratification plane is horizontal and the other inclined.

MONOCLINIC: (μόνος, single; κλίνω, I incline). Dana's name for the oblique system in crystallography.

MONOCOTYLEDONOUS: (μόνος, single; κοτυληδών, seed lobe). Endogenous: the great subdivision of phanerogamous or flowering plants, distinguished by having seeds with one lobe or cotyledon, leaves with subparallel and generally simple veins, and the wood not in concentric layers.

MONOMETRIC: (μόνος, single; μέτρον, a measure). A name formerly used by Dana for the cubical system in crystallography.

MONSOONS: (a corruption of *mausim*, a season, Hindi). Seasons of the year distinguished by the prevalence of winds which blow in opposite directions at different periods.

MORAINE: (French, of Switzerland). The accumulation of angular fragments of rock at the termination and along the sides of glaciers. The rocks are brought down from the mountains traversed by the glacier, and deposited where the ice melts.

MOORUM: (Dakhani Hindustani). Decomposed rock of any kind. The term is commonly used for partially disintegrated basalt near the surface.

MUSCHELKALK: (German, *muschel*, a shell; *kalk*, limestone). The middle group of the triassic formation.

MUSCOVITE: (from muscovy-glass, an old name). Common mica or potash mica; one of the constituents of granite, gneiss, and mica schist, chiefly a silicate of alumina and potash, with some iron, magnesia, soda, &c., and crystallizing in the prismatic system.

NALA: (Hindi). A rivulet or brook, ditch, canal, ravine or valley. The term is especially applied to a watercourse or ravine.

NATROLITE: (*natron*, soda). A zeolitic mineral, crystallizing in the prismatic system, usually assuming acicular forms, and consisting of hydrous silicate of alumina and soda.

NAUTILUS: (ναυτίλος, a sailor). A genus of tetrabranchiate cephalopodous *Mollusca* with coiled chambered shells, allied to *Ammonites*, but distinguished by having simple sutures. Some species are still living.

NEOCOMIEN: (*Neocomum*, Neufchatel). The lower subdivision of the cretaceous system.

NEOGENE: (νέος, new; γίγνομαι, I am formed). A term used by German geologists for all tertiary beds of later age than eocene.

NEOZOIC: (νέος, new; ζωή, life). All formations from the trias upwards, including both mesozoic and cænozoic or tertiary. The term is used in contradistinction to palæozoic.

NEPTUNIAN: (*Neptunus*, god of the sea). The stratified or aqueous deposits are thus termed in contradistinction to plutonic or igneous.

NEW RED SANDSTONE. The sandstones, permian and trias, above the coal measures in the British Islands.

NODULE. An aggregation of a mineral, such as carbonate of lime or silica around a nucleus, or central point.

NOEGGERATHIA: (named after Nöggerath, a botanist). A genus of plants of somewhat doubtful affinity, found in palæozoic rocks. The original types are now referred to *Cycadeaceæ*, but it is uncertain how far the various forms referred to the genus are really congeneric.

NULLAH. See "*Nala.*"

NUMMULITE: (*nummus*, a coin). A genus of *Foraminifera*, consisting of lenticular shells composed of chambers arranged in a spiral. Nummulites are so abundant in eocene beds as to be characteristic.

OBLIQUE. A system in crystallography in which the three axes are unequal, and whilst two of the axial intersections are rectangular, one is oblique.

OBSIDIAN. A lava that has cooled rapidly and is consequently vitreous, like glass or slag. The term is especially applied to vitreous acidic or trachytic lavas, composed mainly of felspar.

OCHRE. Clay, strongly coloured by oxide of iron.

OLD RED SANDSTONE. The sandstones, now referred to the Devonian period, underlying the coal measures of the British Islands.

OLIGOCENE: (ὀλίγος, little; καινός, recent). A term employed by many German geologists for a subdivision of the tertiary epoch corresponding to the lower miocene and uppermost eocene beds of English geologists.

OLIGOCLASE: (ὀλίγος, little; κλάω, I cleave). A species of felspar, chiefly a silicate of alumina and soda with some lime and potash, crystallizing in the anorthic or triclinic system, and commonly found in granite and other plutonic rocks.

OLIVINE. A tribasic silicate of magnesia and iron, usually of a greenish colour and translucent, crystallizing in the prismatic system. The transparent forms are known as chrysolite. Olivine is common in basalt, and usually occurs in imbedded grains of a dark yellowish green colour.

OOLITE: (ὠόν, egg; λίθος, stone). Limestone composed of small rounded concretionary particles. From the prevalence of such limestones in the middle secondary rocks, the term 'oolite' has been applied to the system of beds underlying the cretaceous.

OPAL. An amorphous form of silica, having a resinous lustre. Precious opal has a peculiar play of colours.

OPERCULUM: (Lat., a little cover). A shelly or horny appendage to the foot in many gasteropodous *Mollusca*, serving to close the mouth of the shell.

OPHIDIA: (ὄφις, a snake). An order of reptiles comprising the snakes.

ORDER. In animals and plants, a group of inferior rank to a class: thus in the class *Mammalia* the orders are *Primates, Carnivora, Chiroptera, Ungulata*, &c.

ORGANIC REMAINS. Any recognisable parts or impressions of animals or vegetables in a fossil state.

ORIENTAL. A name applied by Mr. Wallace to one of the great zoological regions into which the surface of the earth is divided. The Oriental region, by many zoologists known as the Indian region, includes India, the Burmese and Malay countries, Southern China, Java, Sumatra, and Borneo, with the western half of the Malay archipelago.

ORTHOCERAS: (ὀρθός, straight; κέρας, a horn). A genus of cephalopodous *Mollusca* with a chambered shell allied to that of *Nautilus*, but straight, not spiral.

ORTHOCLASE: (ὀρθός, straight; κλάω, I cleave). Common felspar, essentially a silicate of alumina and potash, crystallizing in the oblique or monoclinic system, and forming an important ingredient of granite, gneiss, and many other rocks.

ORTHORHOMBIC: (ὀρθός, straight; ῥόμβος, a rhomb). Dana's name for the prismatic system in crystallography.

OSSIFEROUS: (*os*, a bone; *fero*, I bear). Bone-bearing: applied to beds yielding bones of *Vertebrata*.

OUTCROP. The edge of a bed, where it appears on the surface of the ground.

OUTLIER. A portion of a bed detached from the main area by denudation.

PACHYDERMATA: (παχύς, thick; δέρμα, skin). A mammalian order of Cuvier's, comprising elephants, hyraces, and certain ungulates.

PALÆARCTIC: (παλαιός, ancient; ἄρκτος, a bear, *ursa major*). The great zoological region comprising Europe, Africa north of the Sahara, and all Northern and Central Asia.

PALÆONTOLOGY: (παλαιός, ancient, ὤν, being, λόγος, discourse). The science of ancient forms of life.

PALÆOZOIC; (παλαιός, ancient; ζωή, life). The lowest great division of stratified rocks, comprising the permian, carboniferous, devonian, silurian, cambrian, and laurentian systems.

PEAT. A brown or black carbonaceous substance formed in marshes from vegetable tissue by a process of chemical change. In Western Europe peat is mainly derived from the growth and decay of a kind of moss.

PEGMATITE: (πῆγμα, anything fastened together). Usually, a binary granite, composed of quartz and felspar without mica. By some German geologists, the name is applied to a granite containing orthoclase, quartz, and white mica. The term *aplite* is given by German petrologists to the pegmatite of English writers.

PELAGIC, or PELAGIAN: (πέλαγος, the open sea). Formed, living or deposited in the deep sea. The term is used in opposition to littoral or estuarine.

PELECYPODA: (πέλεκυς, an axe; πούς, foot). A term used by some naturalists instead of *Lamellibranchiata, q. v.*

PERCHED BLOCKS. Fragments of rocks transported by glaciers and left isolated on slopes of hills.

PERIOD. A subdivision of geological time.

PERISSODACTYLA: (περισσός, uneven; δάκτυλος, toe). A subdivision of the *Ungulata* distinguished by having an odd number of digits, and comprising horses, rhinoceroses, tapirs, *Palæotheria*, &c.

PERMIAN. The highest subdivision of palæozoic rocks, resting upon the carboniferous, and overlaid by triassic beds. The name is derived from the district of Perm, in Russia.

PETROLEUM: (*petra*, rock; *oleum*, oil). Earth-oil; liquid hydrocarbons found oozing from rocks in places, or occupying cavities, and formed during the slow alteration of organic matter.

PETROLOGY: (πέτρος, rock; λόγος, discourse). The science treating of rocks, their structure and composition.

PETROSILEX. A synonym of felstone or felsite, sometimes applied also to hornstone.

PHANEROGAMIA: (φανερός, apparent; γαμέω, I marry). One of the primary divisions of plants, including all with flowers and cotyledonous seeds. All plants without flowers and with obscure reproductive organization are, on the other hand, classed as *Cryptogamia*.

PHLOGOPITE: (φλογωπός, fire-like, in allusion to its colour). A kind of mica consisting essentially of silicate of alumina and magnesia, usually of a red colour, and often occurring associated with serpentine or crystalline limestone.

PHONOLITE: (φωνή, sound; λίθος, stone). A felspathic volcanic rock, known also as clinkstone; a compact mass, usually of a greenish grey colour, with here and there cleavage surfaces of vitreous felspar. This rock is named from its ringing sharply when struck by a hammer.

PISCES: (Lat.). Fish: a class of the subkingdom *Vertebrata*.

PISOLITE: (*pisum*, a pea). A concretionary limestone similar to oolite, but of coarser texture, the concretions being larger.

PITCHSTONE. A vitreous, dark-coloured rock of igneous origin allied to obsidian, but less glassy, of resinous lustre, and frequently containing small crystals and grains of quartz, felspar, &c.

PLACOID: (πλάξ, a flat plate; εἶδος, form). An order of fishes with flat smooth integument. This order comprises the sharks and rays.

PLAGIOCLASE: (πλάγιος, oblique; κλάω, I cleave). A name proposed by Breithaupt for the group of triclinic felspars, albite, oligoclase, labradorite, and anorthite.

PLEISTOCENE[1]: (πλεῖστος, most; καινός, recent). Post-tertiary or post-pliocene.

PLESIOSAURUS: (πλησίος, near; σαύρα, lizard). An extinct genus of marine reptiles somewhat allied to *Ichthyosaurus*, having, in a similar manner, limbs converted into paddles, and occurring in mesozoic strata. The neck is usually produced and the head small.

PLIOCENE: (πλειών, more; καινός, recent). The uppermost great subdivision of tertiary strata.

PLUTONIC: (*Pluto*, god of Hades). Igneous rocks formed beneath the surface of the earth and not erupted.

POIKILITIC[2]: (ποικίλος, many coloured). A term proposed originally as an equivalent for the New Red Sandstone, comprising both permian and triassic beds. Subsequently the name was used in a more restricted sense, but it has recently been revived by Huxley with its original meaning. At present, when employed, it is generally understood to include both permian and trias.

POLYCYSTINA: (πολύς, many; κύστις, a bladder). The minute siliceous shells of *Radiolaria*.

POLYPE: (πολύς, many; πούς, foot). The animal of a hydrozoan or anthozoan (actinozoan); that is, of a hydroid zoophyte, sea-anemone, or coral.

POLYZOA: (πολύς, many; ζῶον, animal). A synonym of *Bryozoa*, q. v..

PORPHYRY: (πορφύρεος, purple). An igneous rock, composed of a compact finely crystalline mass, in which large crystals of felspar are imbedded. Occasionally other minerals, besides felspar, occur in large crystals, and the term is applied by some geologists to rocks in which any mineral is developed in conspicuous crystalline masses. A *porphyritic* granite, syenite, greenstone, &c., is a rock in which the felspar is in large distinct crystals. The term '*porphyrite*' has been introduced by German geologists for quartzless porphyries consisting of a felsitic base with crystals of felspar, hornblende, or mica; *porphyry* being considered essentially *quartz porphyry* or

[1] This should be written '*plistocene*,' like pliocene.

[2] Correctly '*pœcilitic*.'

elvanite, a compact felsitic mass, with crystals of felspar and quartz.

PREHNITE: (named after the discoverer). A hydrous silicate of alumina and lime, crystallizing in the prismatic system, but usually occurring in reniform crystalline masses associated with zeolites.

PRIMARY: (*primus*, first). A term applied by the earlier geologists to the azoic rocks, and especially to the crystalline formations, granite, gneiss, &c. The name is still occasionally used as synonymous with palæozoic, q. v. *Primitive* has been used in the same signification as primary.

PRIMATES. The highest order of *Mammalia*, including men and monkeys. By Linnæus a more extended meaning was given to the term.

PRISMATIC. A system in crystallography in which the three axes are unequal and all are at right angles to each other.

PROTOGINE: (πρῶτος first; γίγνομαι, I am formed). A granite containing talc or chlorite instead of mica.

PROTOZOA: (πρῶτος, first; ζῶον, an animal). The lowest subkingdom of animals, comprising *Gregarinida*, *Rhizopoda*, and *Radiolaria*. By most naturalists the sponges are also included.

PTEROPODA: (πτερόν, wing; πούς, foot). A class of *Mollusca* in which part of the foot is developed into wing-like processes, with which the animal swims. The *Pteropoda* are pelagic animals, living near the surface of the ocean.

PULMONATA, or PULMO-GASTEROPODA: (*pulmo*, lung). A class of *Mollusca*, distinguished from true *Gasteropoda* by intestinal and reproductive characters. It comprises snails, slugs, pond snails (*Lymneæ*), &c., but not the operculate land shells, *Cyclostoma*, *Helicina*, &c., which are ordinary *Gasteropoda*.

PUMICE. A kind of volcanic froth, the mass of air bubbles from the surface of lava consolidated, and forming a spongy rock, allied to obsidian in composition, but so light as to float upon water.

PYRITE. Iron pyrites; bisulphide of iron, crystallizing in the cubical system.

PYRITES: (πυρίτης from πῦρ, fire): Several sulphides of metals are thus termed; iron pyrites (pyrite), copper pyrites (chalcopyrite), &c. The term used alone generally signifies pyrite.

PYROXENE: (πῦρ, fire; ξένος, a stranger. The name was given by Haüy under the impression that the mineral was not igneous, whereas it is, except felspar, the commonest volcanic mineral). Augite, *q. v.*

PYRAMIDAL. A system in crystallography in which all three axes are at right angles to each other, and two of the three are equal to each other, but not to the third.

QUADRUMANA: (*quatuor*, four; *manus*, hand). A suborder of *Primates*, comprising monkeys.

QUAQUAVERSAL: (*quaqua*, wheresoever; *verto*, I turn). Dipping on every side: applied to the strata which dip in all directions towards or from a common centre.

QUARTZ. Pure silica, crystallizing in the hexagonal system. The word is a German mining term.

QUARTZITE. A metamorphic rock composed entirely, or almost entirely, of silica.

QUARTZ-REEF. A vein of silica traversing other formations.

QUATERNARY. A term used by some geologists for post-tertiary and recent formations.

RACE. A subdivision of a species comprising individuals related by descent.

RADIATA: (*radius*, a spoke). Cuvier's name for one of the primary subdivisions of the animal kingdom. This subkingdom included the modern *Protozoa* and *Cœlenterata*, the *Echinodermata*, and the *Bryozoa*.

RADIOLARIA: (*radiolus*, dim. of *radius*). A class of *Protozoa*, the skeleton of which, when any is present, usually consists of silica. Shells of *Radiolaria* are commonly known as *Polycystina*.

RECENT. In geology, the present epoch; the period during which no important change has taken place in the plants and animals inhabiting the earth.

REH. See p. 413.

REPTILIA: (*repo*, I crawl). A class of *Vertebrata*, comprising, besides crocodiles, lizards, snakes and tortoises, the extinct orders of *Ichthyosauria* and *Plesiosauria*, (which are united by some naturalists into a single order *Enaliosauria*,) *Dicynodontia*, *Pterosauria*, and *Dinosauria*.

RHÆTIC. A group of beds formerly classed in England as lower lias, and in Southern Germany as upper trias, but now separated by many geologists as an intermediate formation, and named from the Rhæti, the ancient inhabitants of the Tyrol. This group is also known as the *Avicula contorta* zone, and in Southern Austria as Kössener-schichten.

RHIZOPODA: (ῥίζα, a root; πούς, a foot). A class of *Protozoa*, comprising the *Foraminifera* and many forms without shells, such as *Amœba*, all of very simple organization, and having the power of thrusting out portions of their body as processes of variable form called '*pseudopodia*.'

RHOMBOHEDRAL: (ῥόμβος, a rhomb; ἕδρα, a side). A name often used instead of hexagonal for the system in crystallography with four axes.

RHYOLITE: (ῥύομαι, I protect). A rock allied to trachyte and felsite in composition. A compact or vitreous matrix enclosing grains or crystals of felspar, mica or quartz. The proportion of silica is larger than in trachyte.

ROCHES MOUTONNÉES. Rocks that have been rounded off and polished by ice action.

ROCK. In geological writings, this word is understood to mean any mineral substance occurring in large masses. Sand and clay in large quantities form rocks, as well as limestone or granite.

ROCK SALT. Common salt occurring as a rock.

RODENTIA: (*rodo*, I gnaw). An order of mammals distinguished by having the anterior teeth in each jaw modified into powerful cutting weapons. Rodents comprise squirrels, rats, porcupines, hares, and a few other forms.

RUMINANTIA: (*rumino*, I ruminate). A subdivision of the mammalian order *Ungulata*, comprising all animals which chew the cud, such as oxen, sheep, antilopes, deer, and camels.

RUTILE: (*rutilus*, red). A mineral composed of titanic acid, crystallizing in the pyramidal system, and occurring, usually, in imbedded crystals, and not unfrequently in acicular forms traversing quartz, in granite, gneiss and other rocks.

SACCHAROID: (*σάκχαρ*, sugar; *εἶδος*, form). A granular structure resembling that of loaf-sugar.

SALIFEROUS OR SALIFERIAN: (*sal*, salt; *fero*, I bear). Salt-bearing: a term applied by some geologists as a distinctive name to the triassic system.

SANDSTONE. A rock composed of sand cemented together.

SAURIAN: (*σαύρα*, lizard). Reptiles, and especially fossil reptiles, akin to lizards.

SCARP. A steep face of rock bounding a bed.

SCHIST: (*σχίζω*, I cleave). A metamorphic rock, having a distinctly foliated structure.

SCHORL. The black opaque variety of tourmaline, common in metamorphic rocks.

SCOLECITE: (*σκώληξ*, a worm; in allusion to its behaviour before the blowpipe). A zeolitic mineral, occurring in acicular crystals, belonging to the oblique system, found chiefly in basaltic rocks, and consisting of hydrous silicate of alumina and lime.

SCORIÆ: (Lat., slag). The vesicular portions of a lava flow, or the equally vesicular fragments ejected from volcanoes during eruption. The term is sometimes used as synonymous with volcanic ash, which is, however, of more general application.

SEAM. A bed or stratum: a term often used for beds of coal.

SECONDARY. A term originally applied to the sedimentary fossiliferous rocks above the primary crystalline strata and below the later or tertiary beds, but subsequently restricted to the formations from the triassic to the cretaceous inclusive, and used as synonymous with mesozoic.

SECTION: (*seco*, I cut). A face of rocks exposed by nature or art, or represented in a drawing.

SEDIMENT. Earthy deposit from mechanical suspension in water.

SEDIMENTARY ROCKS. Rocks formed of sediment.

SENONIAN: (from *Senones*, the Latin name of a people whose chief town was Agendicum, now Sens). A subdivision of the cretaceous system in France, corresponding to the upper chalk of English geologists.

SERIES. A collection of beds comprising several groups, connected by stratigraphical relations or by similarity of organic remains. See "*Group*."

SERPENTINE. A mineral, usually of a greenish colour, consisting of hydrous silicate of magnesia; a rock composed of the mineral in a more or less pure state.

SHALE. A consolidated and well-laminated argillaceous rock.

SHINGLE. Loose pebbles, especially those on the sea-shore.

SILICA: (*silex*, a flint). Silicic acid, a compound of the element silicon and oxygen. Quartz is the same as silica.

SILICEOUS. Composed partly or wholly of silica or quartz.

SILT. Fine sediment from water, especially from rivers.

SILURIAN: (*Silures*, the ancient inhabitants of a part of Western England and Wales). A system or series of lower palæozoic rocks, above the Cambrian and below the Devonian.

SIRENIA: (σειρήν, a siren or mermaid). An order of marine mammals, including the dugong, manatee, and *Rhytina*.

SLATE. A fissile non-crystalline argillaceous rock, the planes of separation in which are not due to bedding, but to cleavage. This is the true geological definition; but the term is often applied to hardened shales, which are bedded, not cleaved, and to schists, which are crystalline.

SLICKENSIDES. A mining term applied to the smoothed and striated surfaces of a fissure along which movement or faulting has taken place.

SOAPSTONE. See "*Steatite*."

SPAR. A common term for mineral crystals.

SPECIES. All plants or animals which resemble each other so closely in all characters, that it is convenient to call them by one name, form a species. They are supposed to be in general more closely connected by descent than different species are; but this rule is not quite accurate or certain. The term was originally applied to all individuals supposed to be descended from one pair, or one parent stock; but the definition is no longer considered sufficient, as it is believed that different species are connected by descent, and that specific distinction is frequently a matter of convenience in classification.

SPINEL. A mineral composed essentially of alumina and magnesia, the magnesia being sometimes replaced by lime or iron protoxide. Spinel crystallizes in the cubical system, and generally occurs in octohedra.

SPONGIDA, or SPONGIOZOA: (σπογγιά, a sponge). Sponges: a class of animals referred by most writers to *Protozoa*, but lately by some naturalists to *Cœlenterata*, and considered by others a distinct subkingdom.

SPORE: (σπορά, seed). The reproductive germ of a cryptogamic plant.

STALACTITE: (σταλάσσω, I drop). Earthy matter forming icicle-like projections, and separated from solution in water, through the evaporation of the latter, whilst trickling down cliffs, or dropping from the roofs of caves. The material is commonly carbonate of lime, less frequently chalcedony or some other mineral.

STALAGMITE: (στάλαγμα, a drop). Projections from the floor of a cave, produced, in the same manner as stalactites from the roof, by the evaporation of water dropping from above, and depositing carbonate of lime or any other mineral from solution.

STEATITE, or SOAPSTONE: (στέαρ, fat). A form of talc; a massive soft mineral, having a waxy lustre and a greasy or soapy feel.

STILBITE: (στίλβη, lustre). A zeolitic mineral: a hydrous silicate of alumina and lime, crystallizing in the prismatic system, and occurring commonly in basaltic rocks.

STRATUM: pl. STRATA: (*stratus*, spread). A bed or layer of a sedimentary rock.

STRIKE. A line drawn along a bed at right angles to the dip, being the intersection between the plane formed by the bed and the earth's surface, if horizontal. The line of outcrop of any stratum on level ground.

SUBCRYSTALLINE. Imperfectly crystalline. The prefix *sub*, under, indicates that the word to which it is added is to be understood as employed in a minor or inferior degree.

SUB-HIMALAYAS. The low ranges, along the southern base of the Himalayas, composed of tertiary rocks. The term is also applied to the rocks forming the low ranges in question.

SUBMETAMORPHIC. Partially or imperfectly metamorphic. The term is applied to the transition rocks of India, which are sometimes highly crystalline, but more frequently unaltered.

SYENITE: (from Syene, in Egypt). A plutonic rock, composed of felspar, quartz, and hornblende, and only differing from granite by the substitution of hornblende for mica. This is the signification of the term as employed by English geologists; but by German writers the name is used for a rock composed of orthoclase felspar and hornblende, without quartz, and the quartziferous rock is called syenitic granite.

SYLVINE: (from *Silvius*, a proper name). Native chloride of potassium.

SYMPHYSIS: (σύμφυσις, a growing together). The union of two bones.

SYNCLINAL: (συν, together; κλίνω, I incline). The curvature of strata in a trough or valley like form, the convexity or salient angle being downward.

SYNCLINAL AXIS. A line drawn along the lowest portion of a synclinal curve.

SYSTEM. A term applied in geology to the whole series of beds representing a subdivision of geological time, as the cretaceous system or tertiary system.

TALC: (derivation uncertain; said to be from an Arabic word). A hydrous silicate of magnesia, rarely crystallizing in the prismatic system, more commonly occurring in foliated masses or granular, very soft, and with a pearly lustre. The massive form is known as steatite or soapstone.

TALUS. The loose detritus accumulated by falling from the face of a cliff, precipice or slope, and not rearranged by water.

TERAI. See p. 404.

TERTIARY. The third or upper great division of geological time, including all formations above the cretaceous and below the deposits of the glacial epoch. The name is synonymous with *Cænozoic.*

TETRAGONAL: (τετράγωνος, four-angled). Dana's name for the pyramidal or dimetric system in crystallography.

THOMSONITE: (named after Prof. Thomson). A zeolite, crystallizing in the prismatic system, and consisting of hydrous silicate of alumina, lime and soda. It usually occurs in radiated masses.

TIN-STONE. Oxide of tin, crystallizing in the pyramidal system.

TOURMALINE: (*turamali*, Cingalese). A mineral, crystallizing in the hexagonal system, and commonly occurring in six-sided prisms. It is of variable composition, containing silicic and boracic acid, with alumina and magnesia, iron, soda, potash, or other bases, as well as a small percentage of fluorine. It is common in metamorphic rocks, occurring most frequently in the form of *schorl.*

TRACHYTE: (τραχύς, rough). A volcanic rock, usually of a pale colour, and mainly composed of felspar; a rough mass, frequently with imbedded crystals of sanidine (glassy felspar, a variety of orthoclase). Some hornblende or augite and dark-coloured mica are also present in most trachytes.

TRANSITION: (*transeo*, I go over). The rocks forming a passage from the crystalline gneiss and schists to the fossiliferous sedimentary rocks.

TRAP: (*trappa*, a stair, Swedish; *treppe*, German). A name originally applied to tabular greenstone and basaltic rocks, from their frequently occurring in hills with step-like terraces on the sides. The term subsequently was used in a somewhat vague manner for

all igneous rocks not distinctly granitic. By some geologists the name is now disused; by others it is restricted to stratified lavas, whether basaltic or trachytic, and to intrusive dykes and masses of basalt, greenstone, trachyte, or similar rocks. The term is too generally used to be abandoned; and for the ancient bedded lavas, which cover so enormous an area in India, no term equally expressive exists.

TRAVERTINE: (*Tiburtinus*, from Tibur, near Rome). Calcareous tufa deposited from the water of springs holding lime in solution.

TREMOLITE: (from Tremola, in Switzerland). A variety of hornblende, of a pale and often white colour, usually in fibrous radiated aggregates, and composed of silicate of magnesia and lime.

TRIAS. The lowest subdivision of mesozoic strata, overlying the permian or uppermost palæozoic series. The name is derived from the three groups of which the series consists in Germany and elsewhere.

TRICLINIC: (τρις, thrice; κλίνω, I incline). A name of Dana's for the anorthic system in crystallography.

TRIMETRIC: (τρις, thrice; μέτρον, a measure). A name formerly employed by Dana for the prismatic system in crystallography, now called by him orthorhombic.

TRILOBITA: (τρις, thrice; λοβός, a lobe). A group of *Crustacea* only found in palæozoic rocks, and having some resemblance in general form to a woodlouse. The cephalic shield is longitudinally divided into three by sutures.

TUFA: (Ital.) Any porous vesicular rock. The term is generally restricted to calcareous deposits from springs.

TUFF. A volcanic formation composed of loose material, scoriæ, lapilli, &c., cemented together. The term is especially applied to subaqueous volcanic accumulations.

TUNICATA: (*tunica*, a garment). A synonym of *Ascidioida*: a class of *Molluscoida* without shells.

UNCONFORMABLE: UNCONFORMITY. Strata are unconformable to each other when the lower has suffered from denudation before the deposition of the upper, or, in a minor degree, when the upper overlaps the lower. As a general rule, the planes of deposition in unconformable strata are not parallel to each other, but there are exceptions for instance, the lower bed may have been partially denuded whilst still perfectly horizontal, and a second horizontal bed may be deposited on the denuded surface of the first, without the latter having been disturbed. In this case the bedding planes in both continue parallel, although the two are quite unconformable.

UNGULATA: (*ungula*, a hoof). An order comprising all herbivorous and hoofed mammals, except the *Proboscidea*. It includes the *Pachy-*

dermata and *Ruminantia* of Cuvier, with the exclusion of *Elephas* and *Hyrax.*

UNICLINAL: (*unus*, one; κλίνω, I incline). See "*Monoclinal.*" The term '*uniclinal*' being of improper construction, has been generally abandoned for the synonym.

UNSTRATIFIED. Rocks which do not occur in layers or strata.

VARIETY. A subdivision of an animal or vegetable species founded on minor characters.

VEIN. In geology, a fissure filled with some mineral substance differing from that of the rock around.

VERMES: (Lat., worms). A Linnæan name for several classes of *Invertebrata*, including insects, mollusks, *Zoophyta*, &c. It is now sometimes used as a synonym of *Annelida;* sometimes of *Annuloida.* At p. 286, it is employed in the former signification.

VERTEBRATA: (*vertebra*, a joint, from *verto*, I turn). A primary division or subkingdom of animals comprising all provided with a spine or backbone composed of joints called *vertebræ.* Mammals, birds, reptiles, amphibians, and fishes constitute the subkingdom.

VOLCANIC: (*Vulcanus*, god of fire). Igneous action at the surface of the earth, in contradistinction to *plutonic* action, which takes place beneath the surface.

VOLCANIC ASH. See "*Ash.*"

WACKÉ. A German mining term for a somewhat decomposed state of doleritic and greenstone rocks.

WHIN: WHINSTONE. A Scotch term for basalt or greenstone.

WOLLASTONITE: (named after Dr. Wollaston). Silicate of lime, crystallizing in the oblique system.

ZAMITES. A genus of fossil cycadeaceous plants allied to the existing *Zamia.*

ZECHSTEIN: (German, mine-stone). A German term for the upper subdivision of the permian series, corresponding to the magnesian limestone of England.

ZEOLITE: (ζέω, I boil). A group of minerals, hydrous silicates of alumina and various earths and alkalies, all characterized by intumescence before the blowpipe. Several of the species are common in amygdaloidal volcanic rocks, filling the cavities.

ZIRCON: (from *jargon*, an old term for the gem). Silicate of zirconia, crystallizing in the pyramidal system. Zircons are found in some crystalline rocks.

ZOOPHYTA: (ζῶον, an animal; φυτόν, a plant). A term applied to the animals of *Hydrozoa*, sea-anemones and corals, or to all typical sessile *Cœlenterata*, and sometimes to *Bryozoa.*

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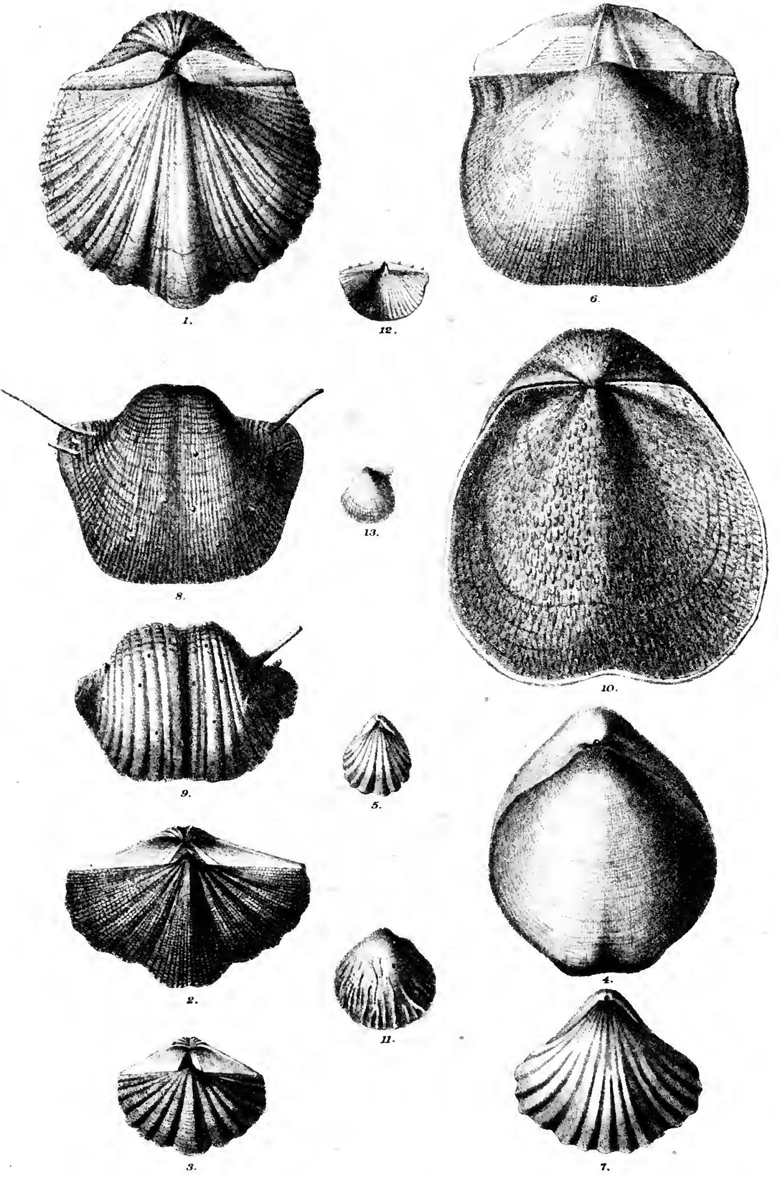
PLATE I.

CARBONIFEROUS FOSSILS (Marine).

Fig. 1. SPIRIFER KEILHAVII, Buch. (*S. rajah*, Salter.)
„ 2. S. MOOSAKHAILENSIS, Davidson. Half natural size.
„ 3. SPIRIFERINA OCTOPLICATA, Sowerby.
„ 4. ATHYRIS SUBTILITA, Hall, var. *grandis*, Dav.
„ 5. RETZIA RADIALIS, Phillips, var. *grandicosta*, Dav.
„ 6. CAMEROPHORIA PURDONI, Dav.
„ 7. STREPTORHYNCHUS CRENISTRIA, Phil.
„ 8. PRODUCTUS SEMIRETICULATUS, Sow.
„ 9. P. COSTATUS, Sow. Half natural size.
„ 10. P. PURDONI, Dav.
„ 11. STROPHALOSIA MORRISIANA, King.
„ 12. CHONETES HARDRENSIS, var. *thibetensis*, Dav.
„ 13. AVICULO-PECTEN HYEMALIS, Salter.

N. B.—All are of natural size, unless the proportions are mentioned.



J. Schaumburg. fect.

S. Sedgfield. imp:

CARBONIFEROUS FOSSILS.

PLATE II.

TRIASSIC FOSSILS (Marine).

Fig. 1. AMMONITES FLORIDUS, Wulfen. Half natural size.

„ 2. A. (CERATITES) THUILLIERI, Oppel. Half natural size.

„ 3. A. DIFFISUS, Hauer.

„ 4. CLYDONITES OLDHAMIANUS, Stoliczka.

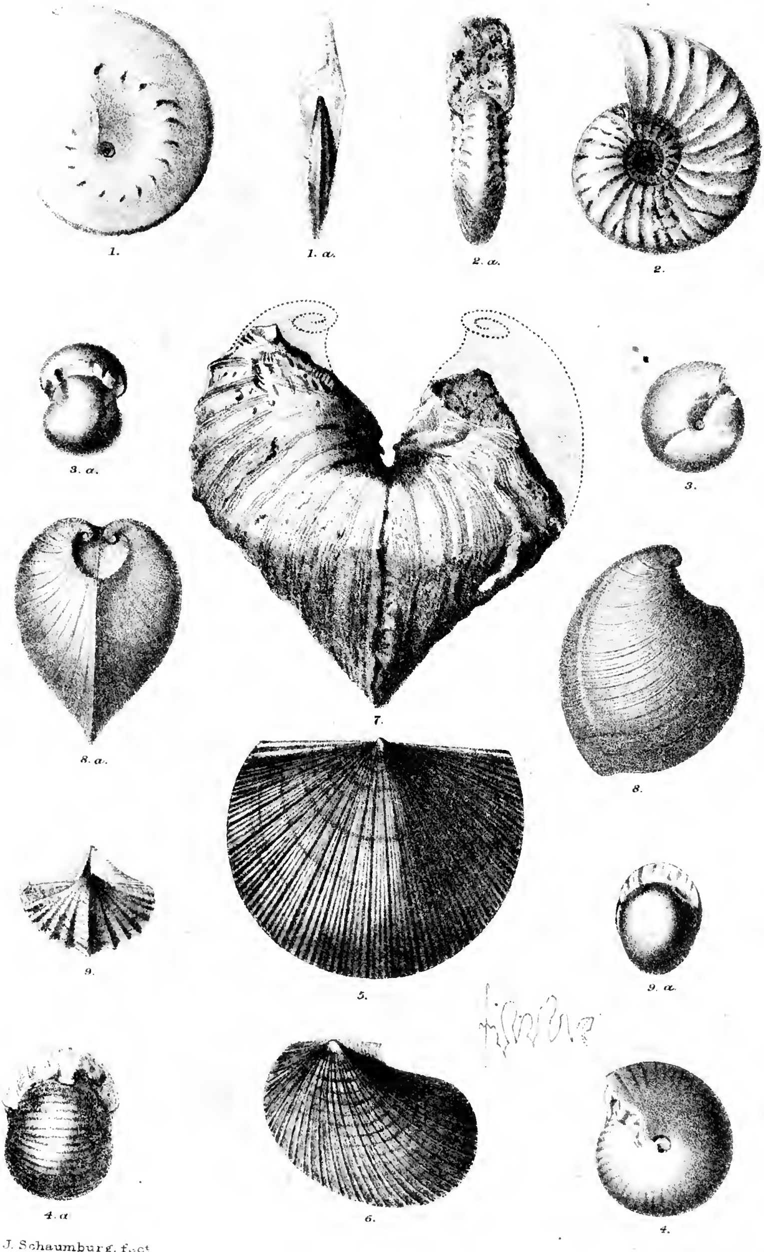
„ 5. HALOBIA LOMMELI, Wissm.

„ 6. MONOTIS SALINARIA, Bronn. Half natural size.

„ 7. DICEROCARDIUM HIMALAYENSE, Stol. One-third natural size.

„ 8. MEGALODON TRIQUETER, Wulfen. Half natural size.

„ 9. SPIRIFER STRACHEYI, Salter.



J. Schaumburg, fect. S. Sedgfield, imp.

TRIASSIC FOSSILS.

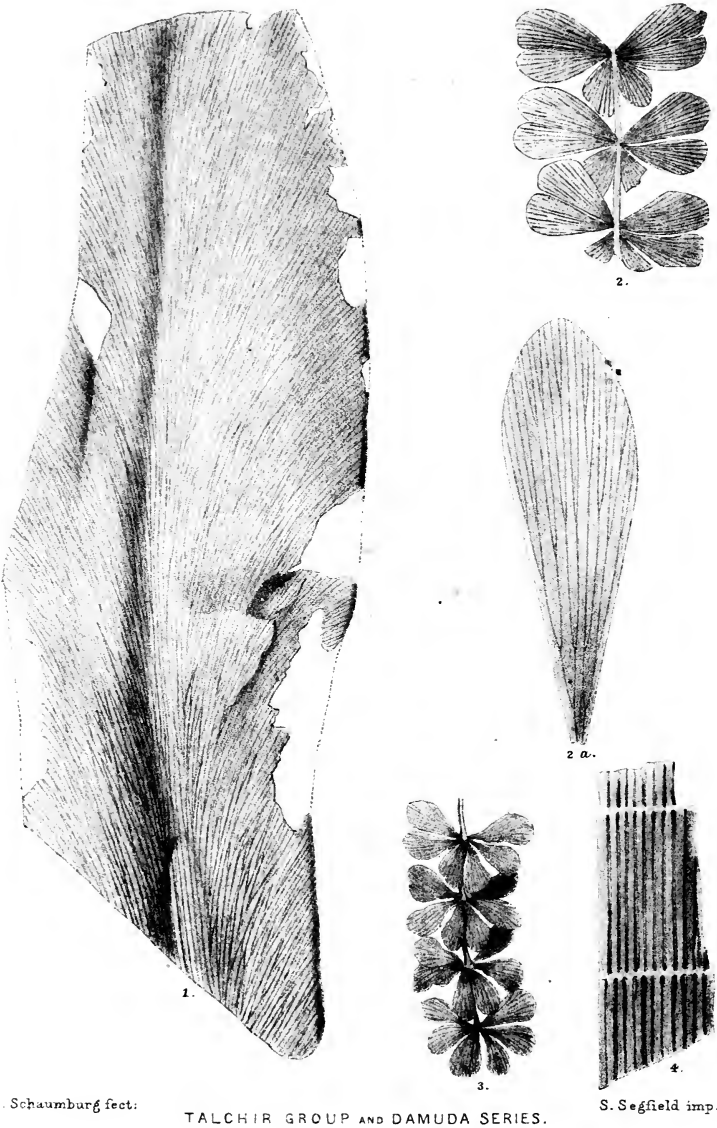
PLATE III.

TÁLCHIR AND DAMÚDA FOSSIL PLANTS.

Fig. 1. GANGAMOPTERIS CYCLOPTEROIDES, Feistmantel.

„ 2 & 3. SPHENOPHYLLUM SPECIOSUM, Royle, sp. (*S. trizygia*, Unger).

„ 4. PHYLLOTHECA INDICA, Bunbury.



J. Schaumburg fect: S. Segfield imp.

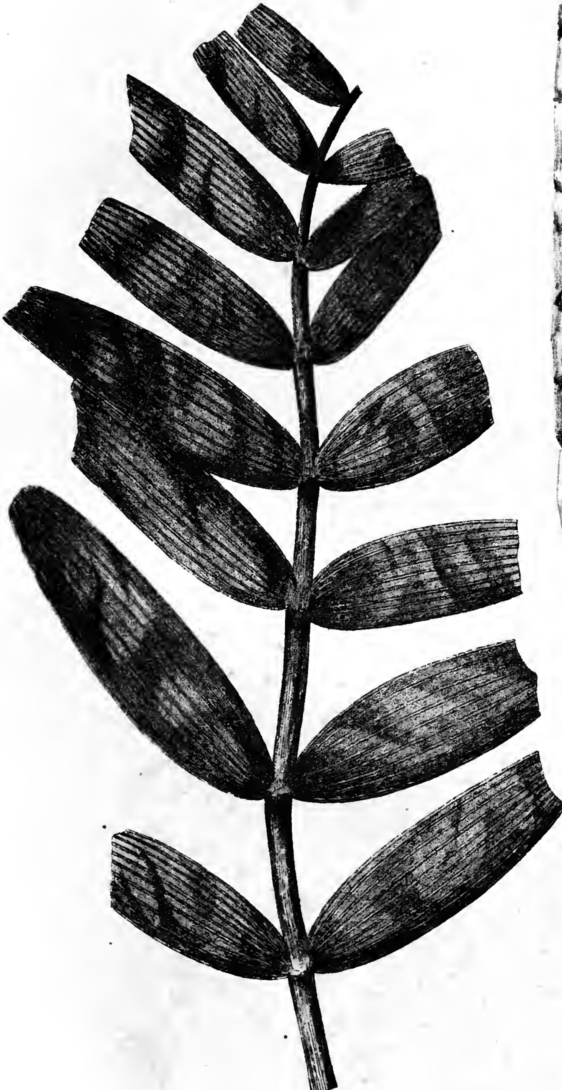
TALCHIR GROUP AND DAMUDA SERIES.

PLATE IV.

DAMÚDA FOSSIL PLANTS.

Fig. 1 & 3. Schizoneura gondwanensis, Fstm.

" 2. Vertebraria indica, Royle.



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J. Schaumburg fect: S. Sedgfield imp:

DAMUDA SERIES.

PLATE V.

DAMÚDA FOSSIL PLANTS.

Fig. 1, 2 & 3. PHYLLOTHECA INDICA, Bunbury. Leaves.

„ 4. GLOSSOPTERIS INDICA, Schimper.

„ 5. G. RETIFERA, Fstm. sp., nov.

„ 6. G. ANGUSTIFOLIA, Brogniart.

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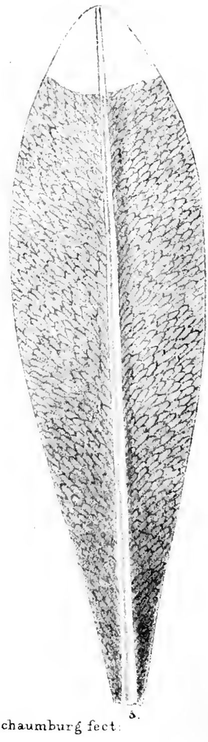

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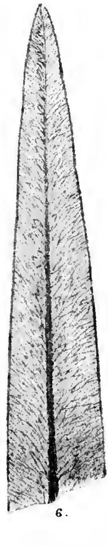

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DAMUDA SERIES.

PLATE VI.

KARHARBÁRI AND DAMÚDA FOSSIL PLANTS.

Fig. 1. VERTEBRÁRIA INDICA, Royle.

„ 2. SPHENOPTERIS POLYMORPHA, Fstm.

„ 3. TÆNIOPTERIS (*Macrotæniopteris*) DANÆOIDES, Royle, sp.

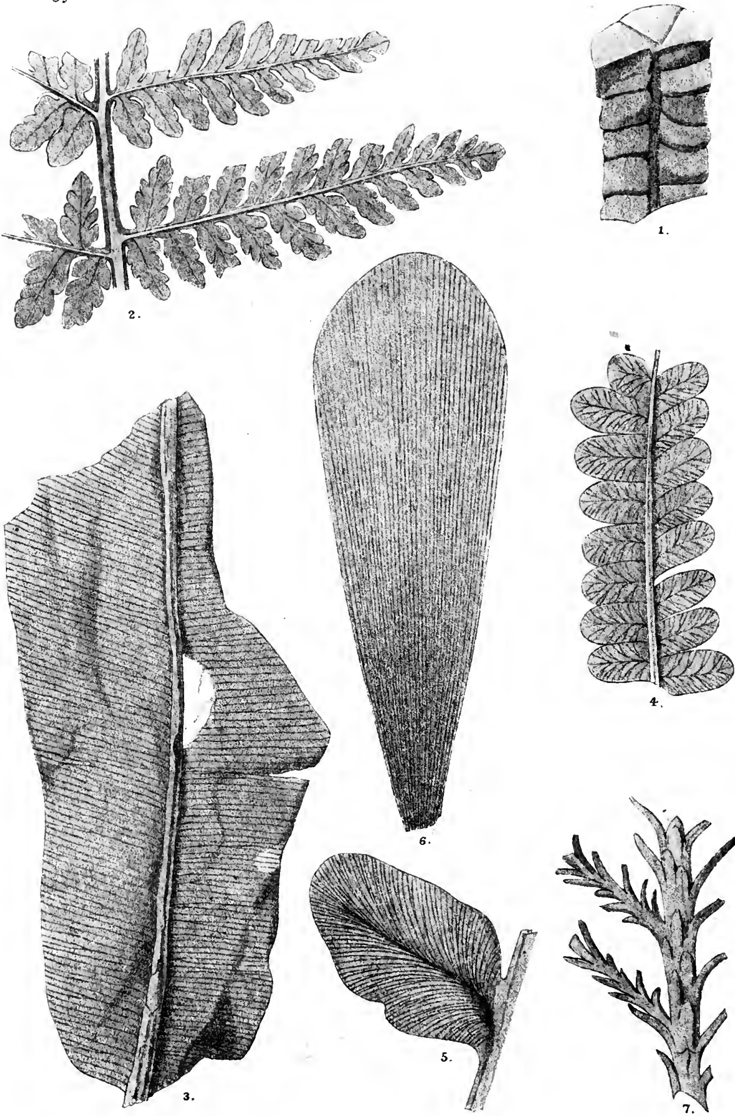
„ 4. ALETHOPTERIS LINDLEYANA, Royle, sp.

„ 5. NEUROPTERIS VALIDA, Fstm.

„ 6. NOEGGERATHIA HISLOPI, Bunbury.

„ 7. VOLTZIA HETEROPHYLLA, Bgt.

N. B.—*Neuropteris valida* and *Voltzia heterophylla* are Karharbári species, and should have been figured with the Tálchir *Gangamopteris cyclopteroides* on Plate III. The relations of the Karharbári group were not determined until after these plates were printed.



J. Schaumburg fect:

DAMUDA SERIES.

S. Sedgfield imp:

PLATE VII.

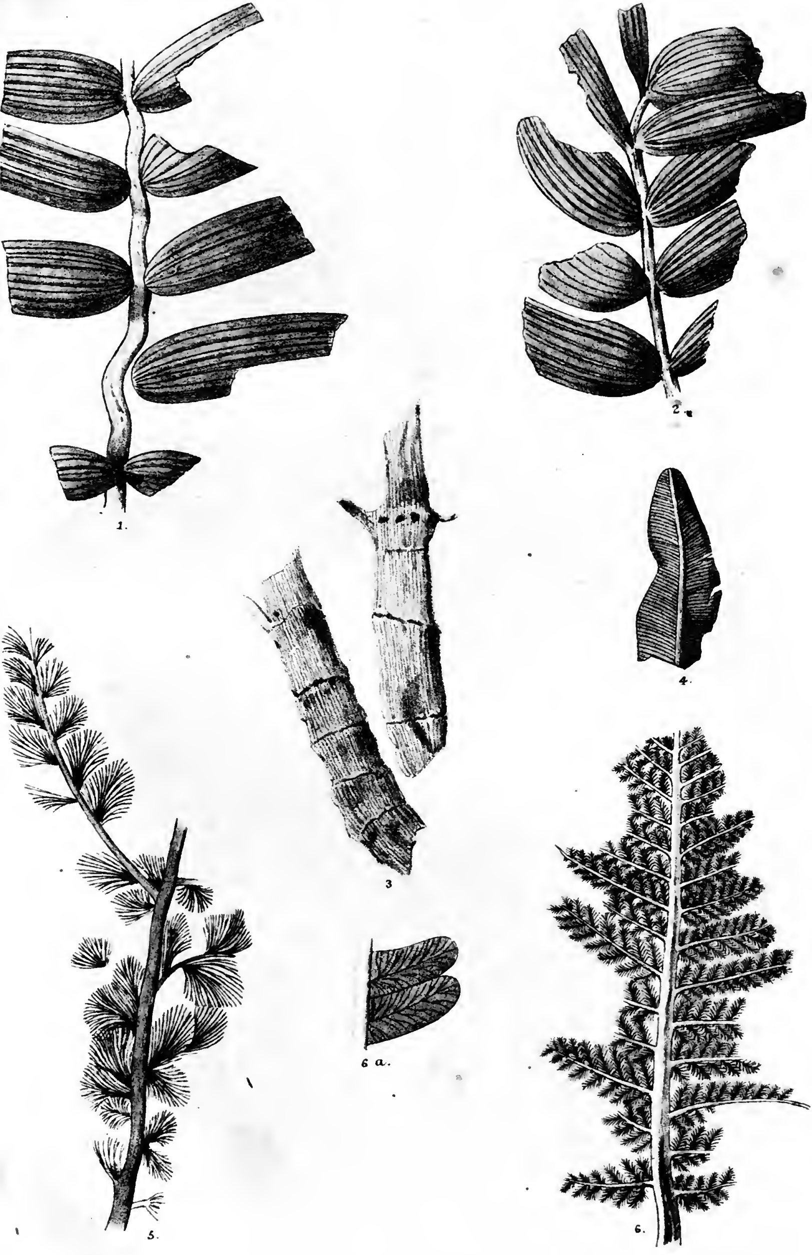
PANCHET FOSSIL PLANTS.

Fig. 1, 2 & 3. SCHIZONEURA GONDWANENSIS, Fstm.

„ 4. TÆNIOPTERIS (*Oleandridium*), sp., allied t [illegible]. *stenoneuron*, Schenk.

„ 5. CYCLOPTERIS PACHYRACHIS, Göppert.

„ 6. PECOPTERIS CONCINNA, Presl.



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PANCHET GROUP.

PLATE VIII.

RÁJMAHÁL FOSSIL PLANTS.

Fig. 1. Ptilophyllum acutifolium, Morris.

„ 2. Pterophyllum rajmahalense, Morris.

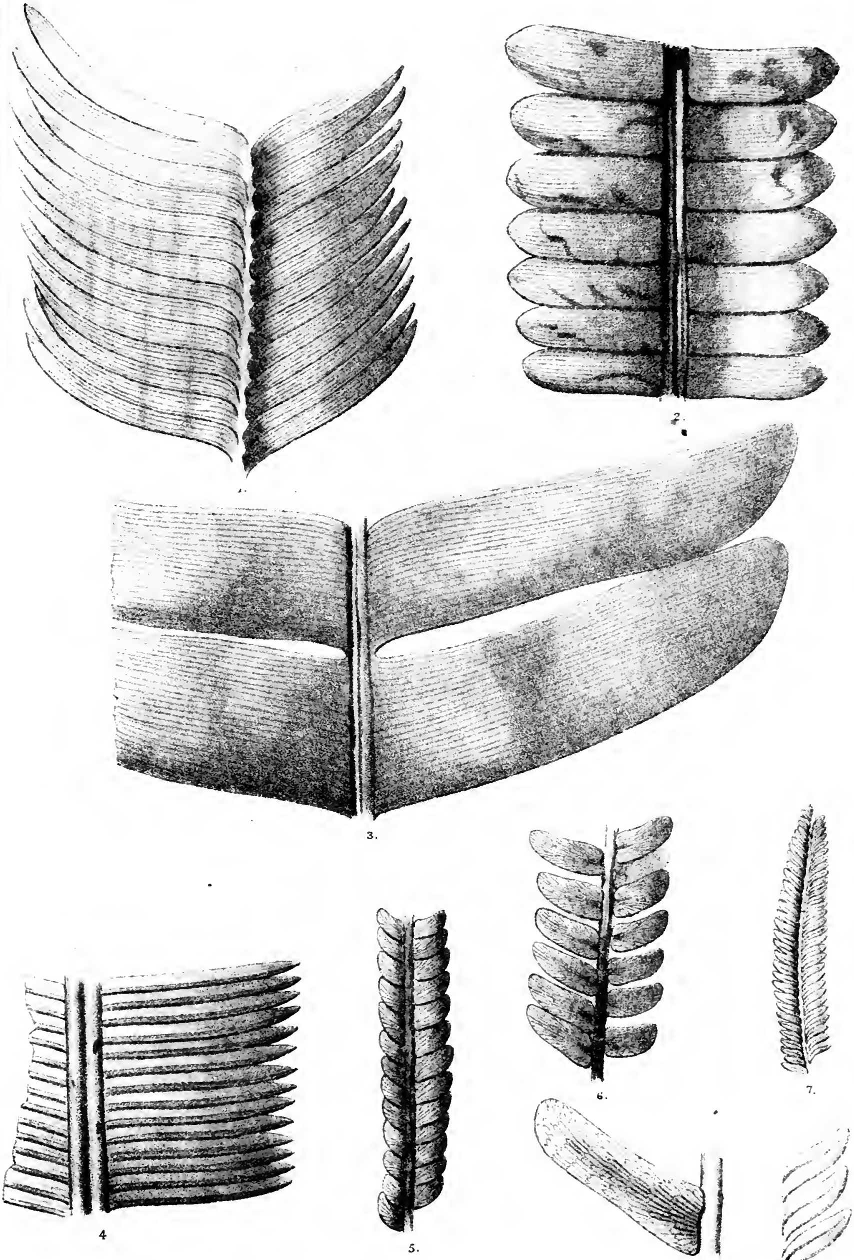
„ 3. P. princeps, Oldham and Morris.

„ 4. Cycadites confertus, Morris.

„ 5. Otozamites bengalensis, Oldham, sp.

„ 6. Dictyozamites falcatus, Morris, sp.

„ 7. Palissya conferta, Oldham, sp.



Schaumburg fec^t   S. Sedgfield imp.

RAJMAHAL GROUP.

PLATE IX.

RÁJMAHÁL FOSSIL PLANTS.

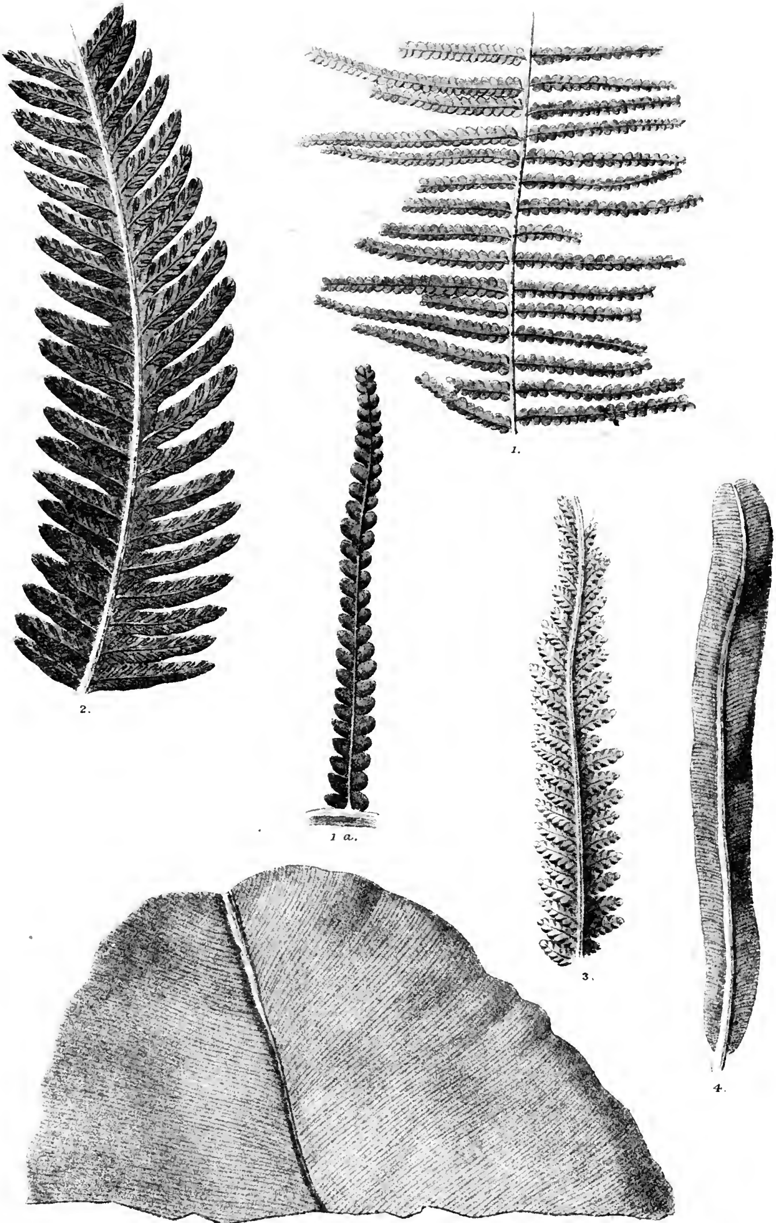
Fig. 1. GLEICHENIA BINDRABUNENSIS, Schimper; (*Pecopteris* [*Gleichenites*] *gleichenoides*, O. and M.)

„ 2. ALETHOPTERIS INDICA, O. and M.

„ 3. PECOPTERIS LOBATA, O. and M.

„ 4. TÆNIOPTERIS (*Angiopteridium*) SPATHULATA, McClelland, sp.

„ 5. T. (*Macrotæniopteris*) LATA, Oldham.



J. Schaumburg, Lith. S. Sedgfield, imp:

RAJMAHAL GROUP.

PLATE X.

JABALPUR FOSSIL PLANTS.

Fig.	1.	ALETHOPTERIS MEDLICOTTIANA, Oldham.
„	2.	OTOZAMITES GRACILIS, Kurr, sp.
„	3.	O. HISLOPI, Oldham.
„	4 & 5.	PODOZAMITES LANCEOLATUS, Lindley and Hutton, sp.
„	6 & 7.	BRACHYPHYLLUM MAMMILLARE, L. and H.
„	8.	PALISSYA JABALPURENSIS, Fstm.
„	9.	P. INDICA, Oldham, sp.
„	10 & 11.	ARAUCARITES CUTCHENSIS, Fstm.

J. Schaumburg fect: S. Sedgfield imp:

JABALPUR GROUP.

PLATE XI.

UMIA (CUTCH) FOSSIL PLANTS.

Fig. 1. TÆNIOPTERIS (*Oleandr idium*) VITTATA, Bgt.

„ 2. ALETHOPTERIS WHITBYENSIS, Bgt., sp.

„ 3 & 4. PTILOPHYLLUM CUTCHENSE, Morris.

„ 5. ECHINOSTROBUS EXPANSUS, Sternberg, sp.

„ 6. PACHYPHYLLUM DIVARICATUM, Bunbury, sp.

„ 7 & 8. ARAUCARITES CUTCHENSIS, Fstm.

J. Schaumburg fec.t S. Sedgfield imp:

KACH GROUP.

PLATE XII.

JURASSIC FOSSILS (*Marine*).

Fig. 1. Belemnites gerardi, Oppel. Half natural size.

„ 2. B. grantianus, D'Orbigny; (*B. kuntkotensis*, Waagen). Half natural size.

„ 3. Ammonites (*Phylloceras*) disputabilis, Zittel. Half natural size.

„ 4. A. (*Aspidoceras*) perarmatus, Sow. One-third natural size.

„ 5. A. (*Stephanoceras*) macrocephalus, Schlotheim. One-fourth natural size.

„ 6. A. (*Perisphinctes*) pottingeri, Sow. One-third natural size.

„ 7. Goniomya v-scripta, Agassiz. Half natural size.

„ 8. Pholadomya granosa, Sow. Half natural size.

„ 9. P. angulata, Sow. Half natural size.

„ 10. Trigonia clavellata, Lind. Half natural size.

„ 11. T. smeei, Sow. One-third natural size.

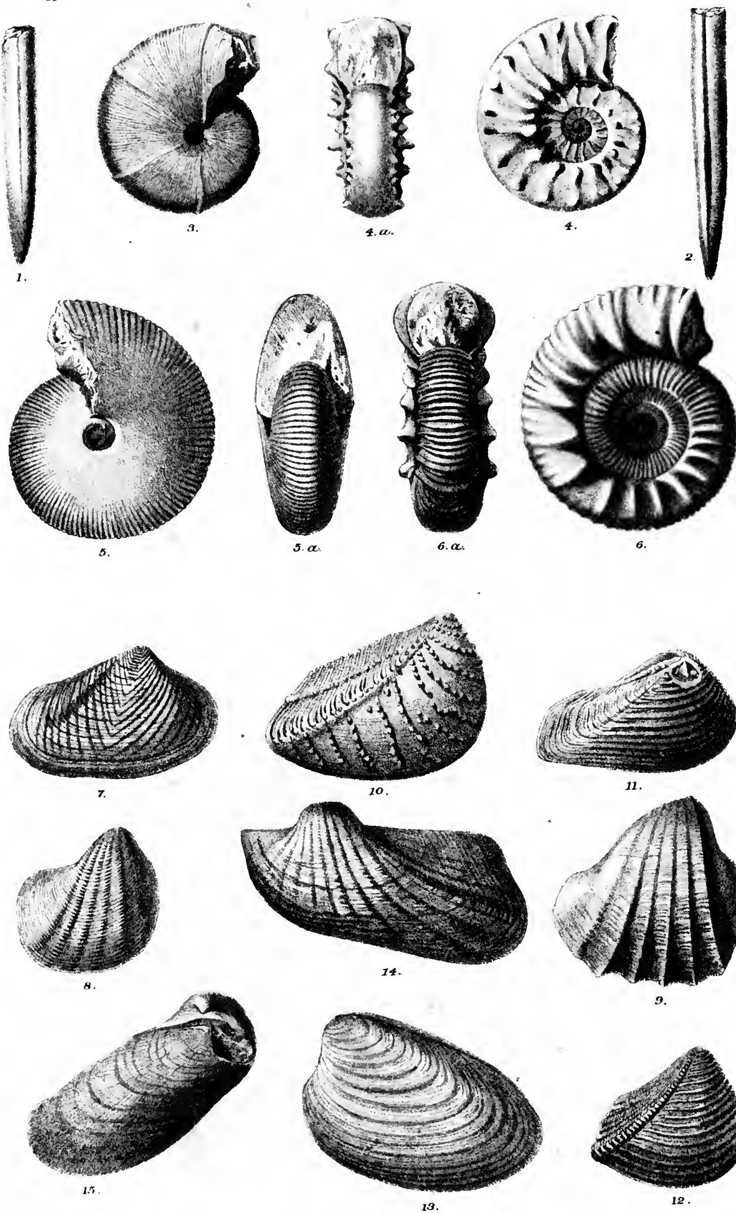
„ 12. T. costata, Parkinson. Half natural size.

„ 13. Astarte major, Sow. One-third natural size.

„ 14. Arca (*Macrodon*) egertoniana, Stol.

„ 15. Aucella leguminosa, Stol.

N. B.—Goniomya v-scripta and *Trigonia clavellata* are not known to occur in India.



J. Schaumburg, fect.

S. Sedgfield, imp:

JURASSIC FOSSILS.

PLATE XIII.

CRETACEOUS FOSSILS (Marine).

Fig. 1. AMMONITES ROTOMAGENSIS, Defrance. One-third natural size.

„ 2. A. PLANULATUS, Sow. Half natural size.

„ 3. TURRILITES COSTATUS, Lamarck. Half natural size.

„ 4. BACULITES VAGINA, Forbes. Half natural size.

„ 5. APORRHAIS SECURIFERA, Forbes, sp.

„ 6. AVELLANA SCROBICULATA, Stol.

„ 7. CARDIUM (*Protocardium*) HILLANUM, Sow. Half natural size.

„ 8. TRIGONIA SCABRA, Lam.

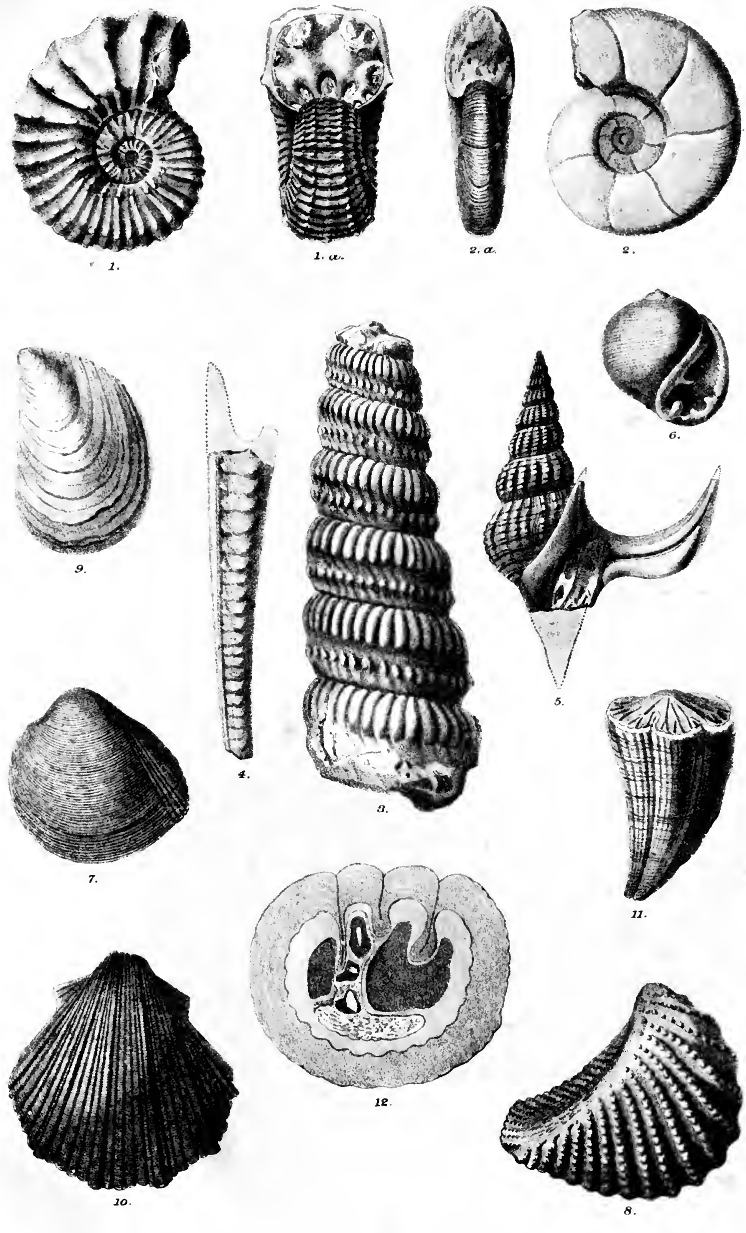
„ 9. INOCERAMUS SIMPLEX, Stol. Half natural size.

„ 10. PECTEN (*Vola*) QUINQUECOSTATUS, Sow.

„ 11. HIPPURITES ORGANISANS, Mont. One-fourth natural size.

„ 12. H. CORNU VACCINUM. Bronn. Transverse section; one-third natural size.

N. B.—The two species of *Hippurites* are not known to occur in India.



J. Schaumburg, fect. S. Sedgfield, imp:

CRETACEOUS FOSSILS.

PLATE XIV.

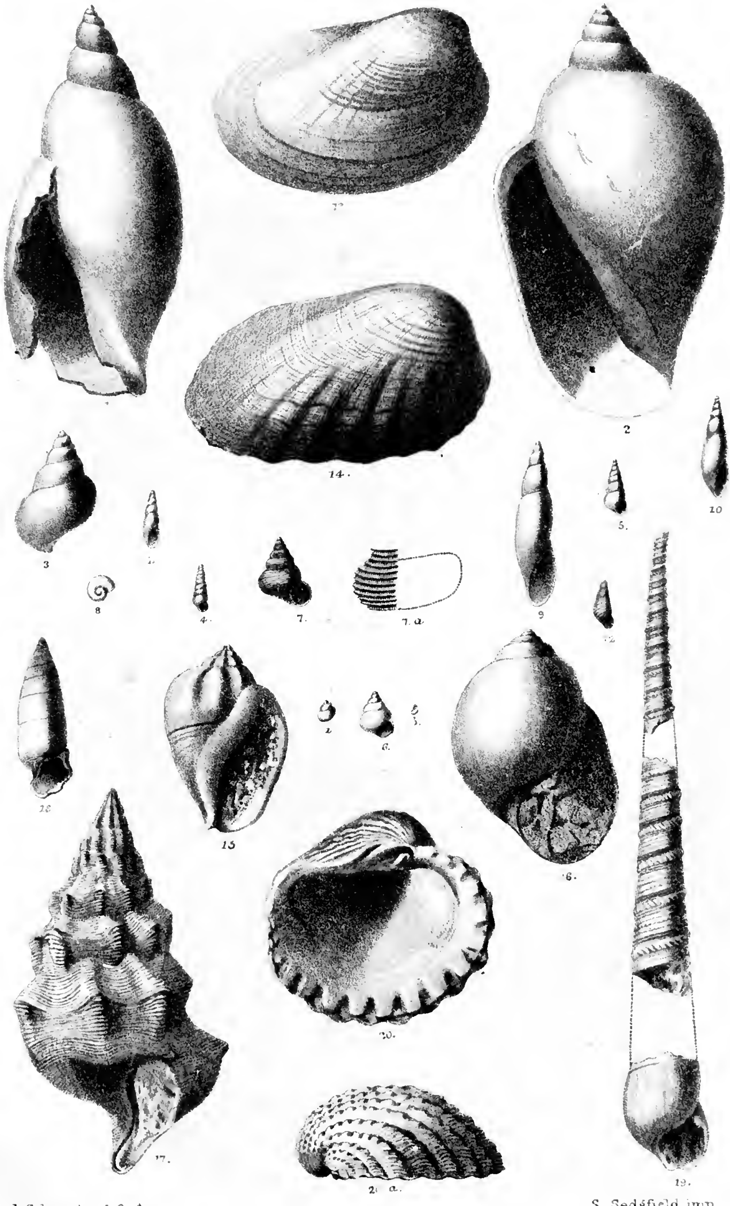
INTERTRAPPEAN FOSSILS (*Upper cretaceous*).

A.—Freshwater.

Fig. 1. Physa prinsepii, Sow. Normal form.
„ 2. P. prinsepii, Sow., var. *elongata*, Hislop.
„ 3. Paludina normalis, Hisl.
„ 4. P. acicularis, Hisl.
„ 5. P. sankeyi, Hisl.
„ 6. P. deccanensis, Sow.
„ 7. Valvata multicarinata, Hisl.
„ 8. Valvata minima, Hisl.
„ 9. Lymnea subulata, Sow.
„ 10. L. telankhediensis, Hisl., var. *peracuminata*.
„ 11. L. spina, Hisl.
„ 12. Melania quadrilineata, Sow.
„ 13. Unio deccanensis, Sow. Half natural size.
„ 14. Unio hunteri, Hisl. Three-fourths natural size.

B.—Estuarine.

Fig. 15. Pseudoliva elegans, Hisl.
„ 16. Natica stoddardi, Hisl.
„ 17. Cerithium stoddardi. Hisl.
„ 18. Vicarya fusiformis, Hisl.
„ 19. Turritella prælonga, Hisl.
„ 20. Cardita variabilis, Hisl.



J. Schaumburg, fec.t S. Sedgfield, imp.

INTERTRAPPEAN FOSSILS.

PLATE XV.

EOCENE NUMMULITIC FOSSILS (*Marine*).

Fig. 1. VOLUTA JUGOSA, Sow.

„ 2. NERITA SCHMEDELIANA, Chemnitz. 2 *a*: cast of the same.

„ 3. PECTEN LABADYEI, D'Archiac and Haime.

„ 4. VULSELLA LEGUMEN, D'Arch. and H.

„ 5. ECHINOLAMPAS DISCOIDEUS, D'Arch. Half natural size.

„ 6. EURHODIA MORRISI, D'Arch. and H.

„ 7. ORBITOIDES PAPYRACEA, Boubée.

„ 8. O. DISPANSA, Sow.; section. 8 *a, b, c, d*: varieties.

„ 9. ALVEOLINA SPHEROIDEA, Lam. Enlarged three diameters. 9 *a*: the same; natural size. 9 *b*: transverse section.

„ 10. NUMMULITES GARANSENSIS, Joly and Leymerie. 10 *a*, 10 *b*: sections of the same enlarged.

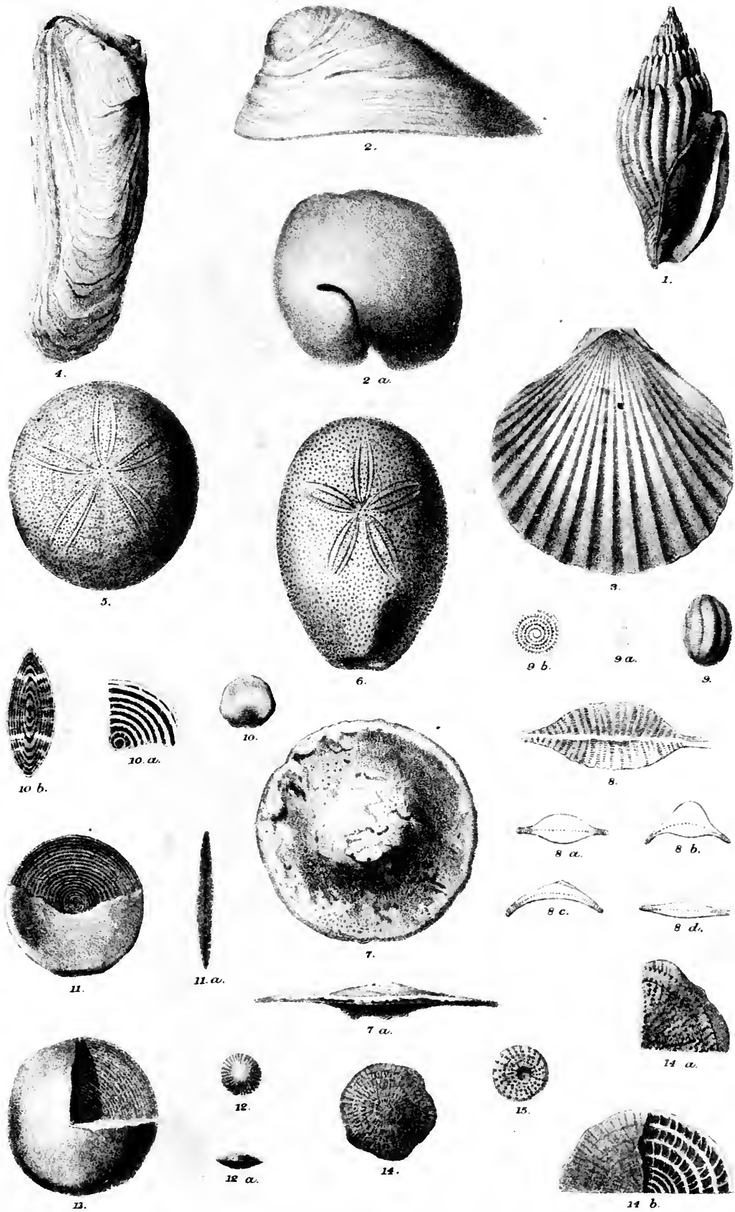
„ 11. N. SUBLÆVIGATA, D'Arch. and H. 11 *a*: section of same.

„ 12. N. RAMONDI, Defr.

„ 13. N. OBTUSA, Sow.

„ 14. N. GRANULOSA, D'Arch.

„ 15. N. LEYMERIEI, D'Arch.



J. Schaumburg, fect. S. Sedgfield, imp:

EOCENE [*older terliary*] FOSSILS.

PLATE XVI.

MIOCENE GÂJ FOSSILS (chiefly Marine).

Fig. 1. Vicarya verneuilli, D'Arch.

„ 2. Turritella angulata, Sow.

„ 3. Ostrea multicostata, Deshayes.

„ 4. Pecten favrei, D'Arch.

„ 5. Arca (*Parallelepipedum*) kurracheensis, D'Arch.

„ 6. A. (*Anomalocardia*) larkhanensis, D'Arch. (*estuarine*).

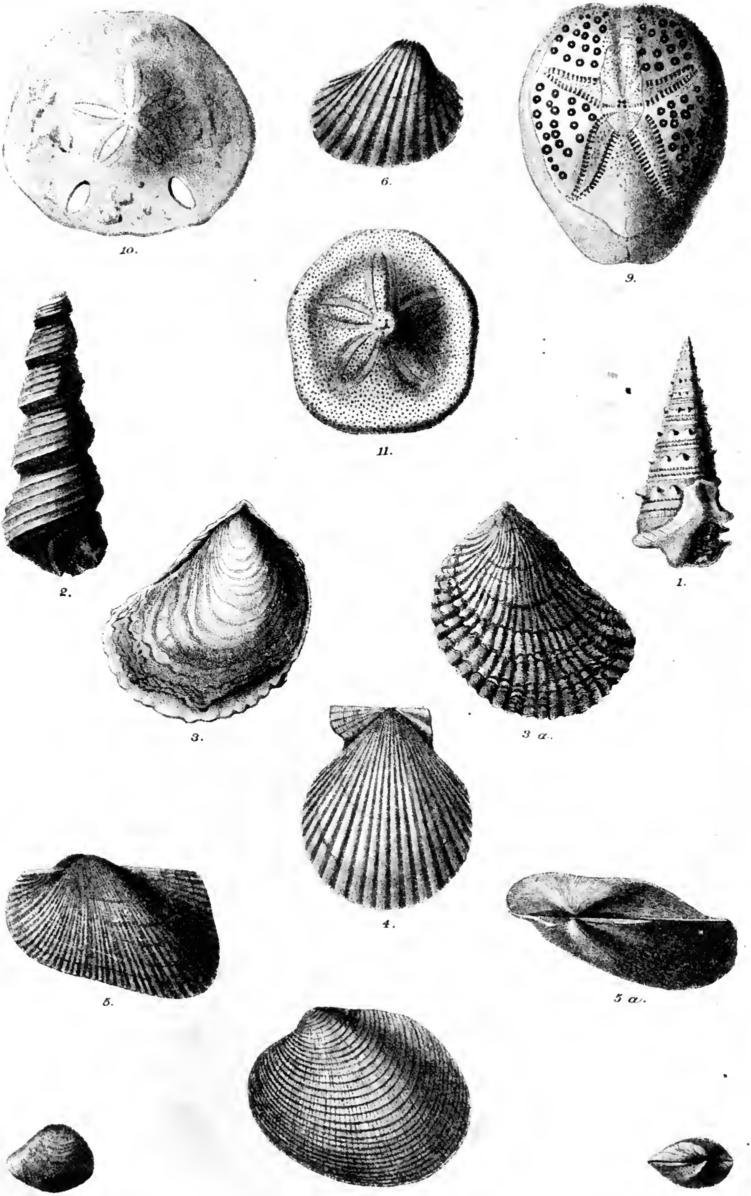
„ 7. Venus granosa, Sow. Half natural size.

„ 8. Corbula trigonalis, Sow. (*estuarine.*)

„ 9. Breynia carinata, D'Arch. and H. Half natural size.

„ 10. Echinodiscus, sp.

„ 11. Clypeaster depressus, Sow. Half natural size.



J. Schaumburg, fect. S. Sedgfield, imp:

MIOCENE FOSSILS.

PLATE XVII.

LATER TERTIARY FOSSIL MAMMALS (*chiefly Siwalik pliocene*).

Fig. 1. ELEPHAS (*Stegodon*) INSIGNIS, Falconer and Cautley. Restored cranium; one-twentieth natural size.

„ 2. E. (*Stegodon*) GANESA, F. and C. Restored cranium; one-twentieth natural size.

„ 3. MASTODON PERIMENSIS, F. and C. Restored cranium; one-twentieth natural size.

„ 4. MASTODON LATIDENS, F. and C. Upper molar; one-third natural size.

„ 5. ELEPHAS (*Euelephas*) HYSUDRICUS, F. and C. Lower molar; one-third natural size.

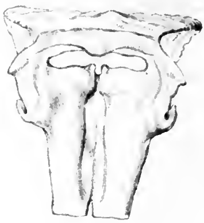
„ 6. MASTODON SIVALENSIS, F. and C. Last upper molar; one-third natural size.

„ 7. ELEPHAS (*Stegodon*) INSIGNIS, F. and C. Upper milk molar; one-third natural size.

„ 8. HIPPOHYUS SIVALENSIS, F. and C. Second upper molar.

„ 9. SUS GIGANTEUS, F. and C. Upper molars.

„ 10. MERYCOPOTAMUS DISSIMILIS, F. and C. Upper molar.



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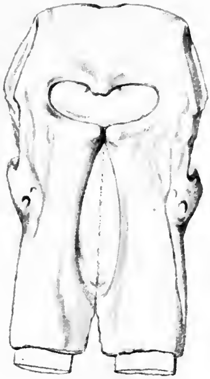

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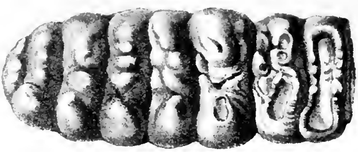

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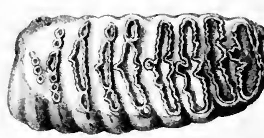

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10.

J. Schaumburg fect.

SIWALIK FOSSILS.

PLATE XVIII.

LATER TERTIARY FOSSIL MAMMALS (chiefly Siwalik pliocene).

Fig. 1. HEMIBOS TRIQUETRICERUS. F. and C. Cranium; one-sixth natural size.

„ 2. AMPHIBOS ACUTICORNIS, F. and C. Cranium; one-sixth natural size.

„ 3. DORCATHERIUM MAJUS, Lydekker. Upper molar.

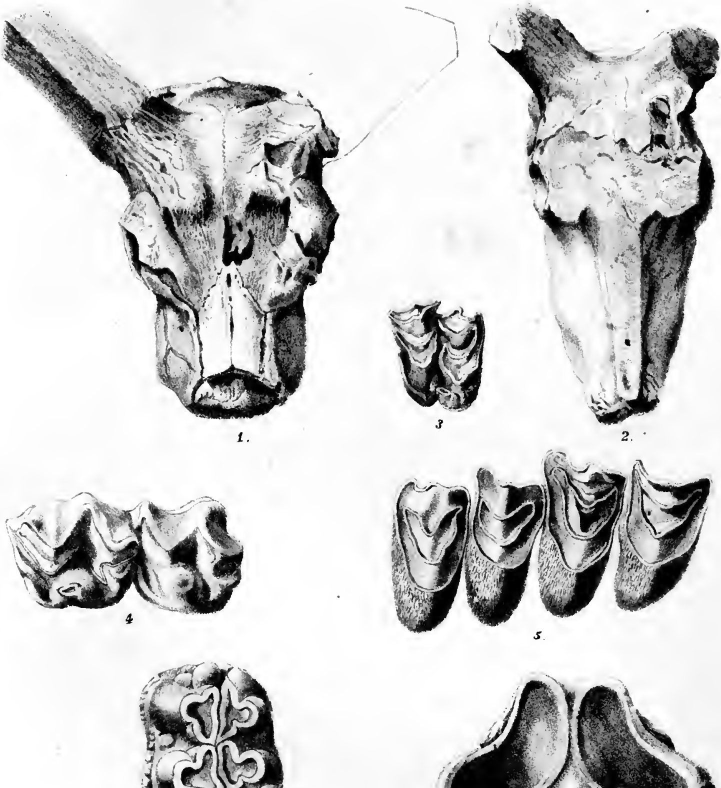
„ 4. CHALICOTHERIUM SIVALENSE, F. and C. Upper molar; half natural size.

„ 5. BRAHMATHERIUM PERIMENSE, Falc. Upper molars; two-thirds natural size.

„ 6. HIPPOPOTAMUS (*Hexaprotodon*) SIVALENSIS, F. and C. Last upper molar; half natural size.

„ 7. SIVATHERIUM GIGANTEUM, F. and C. Restored cranium; one-eighteenth natural size.

„ 8. HIPPOPOTAMUS (*Hexaprotodon*) SIVALENSIS, F. and C. Cranium; one-eighth natural size.



J. Schaumburg fect

SIWALIK FOSSILS.

PLATE XIX.

LATER TERTIARY FOSSIL MAMMALS (*chiefly Siwalik pliocene*).

Fig. 1. RHINOCEROS SIVALENSIS, F. and C. Mandible; one-fourth natural size.

„ 2. R. IRAVADICUS, Lyd. Left upper molar; half natural size.

„ 3. R. SIVALENSIS, F. and C. Upper jaw, right side; one-fourth natural size.

„ 4. AMPHICYON PALÆINDICUS, Lyd. Upper molar (*miocene*).

„ 5. ENHYDRIODON SIVALENSIS, F. and C. Palate; four-ninths natural size.

„ 6. HIPPARION ANTELOPINUM, F. and C. Upper molar.

„ 7. LISTRIODON PENTEPOTAMIÆ, Falc., sp. Upper molar.

„ 8. HYÆNA SIVALENSIS, F. and C. Upper carnassial tooth.

„ 9. HYÆNARCTUS SIVALENSIS, F. and C. Right upper carnassial and molars; three-quarters natural size.

„ 10. HYÆNA SIVALENSIS, F. and C. Upper premolar.

„ 11. SEMNOPITHECUS ? SUBHIMALAYANUS, Meyer. Right upper molars.

„ 12. RHINOCEROS, sp. astragalus. One-fourth natural size.

J. Schaumburg, Lith:

SIWALIK FOSSILS.

S. Sedgfield, imp:

PLATE XX.

POST-TERTIARY FOSSIL MAMMALS (*Narbada*).

Fig. 1. Bos (*Bubalus*) PALÆINDICUS, F. and C. Cranium; one-fifth natural size.

„ 2. HIPPOPOTAMUS (*Hexaprotodon*) NAMADICUS, F. and C. Symphysis of mandible; one-eighth natural size.

„ 3. BOS NAMADICUS, F. and C. Frontlet and part of right horn-core; one-tenth natural size.

„ 4. EQUUS NAMADICUS, F. and C. Upper molars, right side; half natural size.

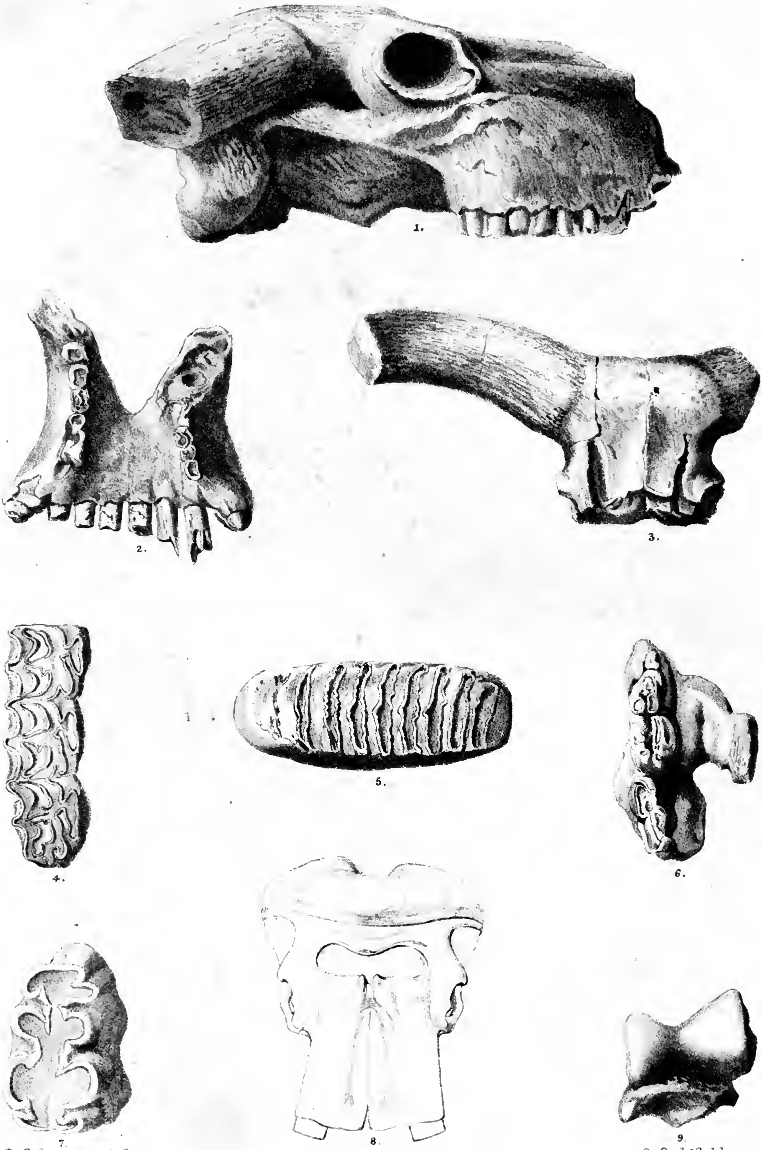
„ 5. ELEPHAS NAMADICUS, F. and C. Lower milk-molar; one-third natural size.

„ 6. URSUS NAMADICUS, F. and C. Part of upper jaw; half natural size.

„ 7. HIPPOPOTAMUS (*Tetraprotodon*) PALÆINDICUS, F. and C. Last upper molar, left side; half natural size.

„ 8. ELEPHAS NAMADICUS, F. and C. Restored cranium; half natural size.

„ 9. RHINOCEROS NAMADICUS, F. and C., astragalus. One-fourth natural size.



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NERBUDDA FOSSILS.

PLATE XXI.

STONE IMPLEMENTS (*Post-tertiary and sub-recent*).

Fig. 1. CHIPPED QUARTZITE IMPLEMENT, 'spear-head' form, from the Narbada valley; two-thirds natural size. This specimen was found in the gravels which contain bones of extinct post-tertiary mammalia. See p. 386.

„ 2. AGATE FLAKE, or knife, from Godávari valley, natural size; also found in gravels containing bones of extinct post-tertiary mammalia. See p. 389.

„ 3. CHERT CORE, found in the bed of the Indus at Sukker, natural size. See p. 442.

„ 4. SMOOTHED CELT of greenstone from Banda, N. W. P.; natural size. See p. 442.

„ 5. SMOOTH AND POLISHED CELT of limestone, adopted for a handle, from Burma; natural size. See p. 442.

J. Schaumburg. fect.

STONE IMPLEMENTS.